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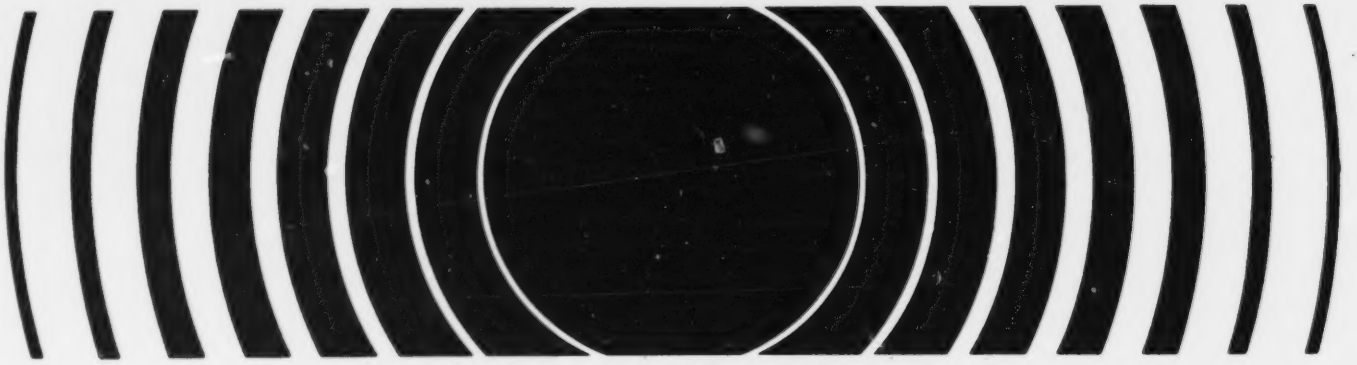

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The ERAMS program is composed of a network of sampling stations throughout the United States plus an associated radioanalystical and assessment support group. These components provide a capability to evaluate environmental consequences from both normal ambient concentrations of radiation and time dependent changes as measured by the samples. The program is structured to measure concentrations of radionuclides in air, milk, surface water, and drinking water and to estimate dose and health impact. Several examples of short-term and long-term assessments of dose and health effect calculations from the ERAMS data base have been presented in this report.

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ANALYTICAL CAPABILITY OF THE ENVIRONMENTAL

RADIATION AMBIENT MONITORING SYSTEM

by

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U. S. Environmental Protection Agency

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April 1983

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FOREWORD

This document provides an introduction to the information available from the Environmental Radiation Ambient Monitoring System (ERAMS) data base. The types of information which may be derived from these data include documentation of ambient environmental radiation levels with their trends, and estimates of dose and health effects due to these ambient levels.

We hope the technical community concerned with radiation hazards, as well as the general public, may gain an understanding of the past, present, and future levels of ambient radiation from information produced in this and subsequent reports.

Readers are encouraged to send comments regarding the material presented herein to:

Technical Publications Office
Eastern Environmental Radiation Facility
P. O. Box 3009
Montgomery, AL 36193

Charles R. Porter, Director
Eastern Environmental Radiation Facility

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1.0 BACKGROUND AND PURPOSE

Continuing surveillance of radioactivity levels in the United States is maintained through EPA's Environmental Radiation Ambient Monitoring System (ERAMS). This system was formed in July 1973 from the consolidation and redirection of separate monitoring networks formerly operated by the U.S. Public Health Service prior to EPA's formation. These previous monitoring networks had been oriented primarily to measurements of fallout. They were modified by changing collection and analysis frequencies and sampling locations and by increasing the analyses for some specific radionuclides. The emphasis of the current system is toward identifying trends in the accumulation of long-lived radionuclides in the environment. However, ERAMS, by design, is flexible and can provide short-term assessments of large scale contaminating events such as industrial releases or fallout.

ERAMS normally involves several thousand individual analyses per year on samples of air particulates, precipitation, milk, and surface and drinking water. Samples are collected at about 280 locations in the United States and its territories, mainly by State and local health agencies (See Table 1). These samples are forwarded to ORP's Eastern Environmental Radiation Facility (EERF) in Montgomery, Alabama for analyses. ERAMS data are tabulated quarterly and issued to the groups involved in the program.*

---

* ERAMS data are published quarterly in the EPA publication Environmental Radiation Data. A summary analysis of ERAMS data will be presented in each year's publication of EPA's Radiological Quality of the Environment in the United States. This publication is available from the Office of Radiation Programs, U.S. EPA, 401 M Street S.W., Washington, D.C. 20460. Previously, ERAMS data were published monthly in Radiation Data and Reports. This publication was terminated in December 1974.

TABLE 1

ERAMS Sampling Stations

ERAMS COMPONENT	NUMBER OF STATIONS	TYPE OF SAMPLE	SAMPLING FREQUENCY
Airborne Particulates and Precipitation	67		
Particulates		Filters from positive displacement air samplers	Filters are changed twice weekly
Precipitation		Precipitation	Collected as precipitation occurs. Composited into into single monthly sample
Pasteurized Milk	65	Composite samples representing > than 80 percent of milk consumed in major population centers	Monthly
Drinking Water	78	Grab samples from major population centers or selected nuclear facility environs	Quarterly
Surface Water	58	Grab samples downstream from nuclear facilities or from background sites	Quarterly

TABLE 2

ERAMS Sample Radiochemical Analysis

ERAMS COMPONENT		ANALYSIS	ANALYTICAL FREQUENCY
Airborne Particulates and Precipitation	Particulates	(1) 5 and 29 hour G.M. field estimates	(1) Each of twice weekly samples.
		(2) Gross beta	(2) Each of twice weekly samples.
		(3) Gamma scans	(3) All samples showing > 1 pCi/m^3 gross beta
		(4) ^{238}Pu, ^{239}Pu, ^{234}U, ^{235}U, ^{238}U	(4) Quarterly on composite samples.
	Precipitation	(1) Tritium	(1) Monthly on composite sample
		(2) Gross beta	(2) Monthly on composite sample
		(3) Gamma scans	(3) Monthly on composite samples showing > 10 pCi/l gross beta
		(4) ^{238}Pu, ^{239}Pu, ^{234}U, ^{235}U, ^{238}U	(4) Annually on Spring quarter composites
Krypton-85		(1) ^{85}Kr	(1) Annually
Pasteurized Milk		(1) ^{131}I, ^{141}Ba, ^{137}Cs, ^{40}K	(1) Monthly
		(2) ^{89}Sr, ^{90}Sr, Ca	(2) Annually on July samples
		(3) ^{89}Sr, ^{90}Sr	(3) January, April, and October-intraregional composites each of EPA's 10 regions
		(4) Tritium	(4) Annually on April samples
		(5) ^{14}C	(5) Annually on 9 selected samples

TABLE 2-Continued

ERAMS Sample Radiochemical Analysis

ERAMS COMPONENT	ANALYSIS	ANALYTICAL FREQUENCY
Drinking Water	(1) Tritium	(1) Quarterly
	(2) Gamma scans	(2) Annually on composite samples
	(3) Gross alpha and beta	(3) Annually on composite samples
	(4) ^{226}Ra	(4) Annually on composite samples
	(5) ^{228}Ra	(5) Annually on composite samples with ^{226}Ra between 2-5 pCi/l
	(6) ^{90}Sr, ^{89}Sr	(6) Annually on composite samples
	(7) ^{238}Pu, ^{239}Pu, ^{234}U, ^{235}U, ^{238}U	(7) Annually on composite samples with gross alpha $\geq$ 2 pCi/l
	(8) ^{131}I	(8) Annually on one individual sample
Surface Water	(1) Tritium	(1) Quarterly
	(2) Gamma scans	(2) Annually on Spring samples

ERAMS is designed to achieve several objectives:

1. provide data on levels of radioactive pollutants for standard-setting, for verification that standards are met, for evaluation of the effectiveness of controls, and for determining environmental trends;
2. provide input to an assessment of the population intake of radioactive pollutants;
3. provide data for developing dose computational models for national dose and health risk;
4. monitor pathways for significant population exposure from major sources of population exposures, such as fallout from atmospheric nuclear weapons tests;
5. provide data that will be used in the event of an accidental release of radioactivity to the environment. Such data could indicate additional sampling needs and other actions required to evaluate public health and environmental quality.

Since its initiation, the ERAMS have provided data on baseline radiation levels in the environment. These data have (1) revealed long-term trends in environmental radiation levels; (2) detected radioactive releases from fuel-cycle facilities; (3) provided preoperational environmental radiation levels prior to nuclear facility installations; (4) allowed the detection and monitoring of fallout from atmospheric nuclear weapons testing by other countries, and (5) provided information to assuage public concerns and give an assessment of public health hazards during periods of fallout or accidental releases of radioactivity. Data that have been obtained from ERAMS during fallout episodes have been consistent with the data obtained from other Federal,

State, and private sampling programs. The ERAMS has provided a continual radiation "picture" of a large portion of the United States. The present data base contains historical information which may be used to predict trends for future environmental radioactivity.

The ERAMS stations are widely dispersed throughout the United States, covering each geographical region, most individual states, and all major population centers. Many stations are located in the near-environment of major potential environmental release points. The present set of stations in order to effectively measure the wide-scale impact from global events.

Furthermore, the ERAMS structure satisfies all three major objectives of an environmental monitoring program, as were set forth by the Health Physics Society's, Ad Hoc Committee on Upgrading the Quality of Environmental Data (Wa80) (EPA-520/1-80-012):

1. to aid in dose assessment;
2. to determine any trends of radiation dose rates and radioactivity concentrations; and
3. to reassure members of the public and governmental organizations.

2.0 MAJOR SAMPLING COMPONENTS OF ERAMS

2.1 Milk Program

The ERAMS Milk Program is a cooperative effort between ORP of EPA, and the Dairy and Lipid Products Branch, FDA. It consists of 65 sampling U.S. Census locations (See Fig. 2.1-1) submitting monthly samples of milk composited by the volume of milk consumed each at each sampling location. Using these data we have calculated that the combined sampling covers more than 80 percent of the milk consumed in major U.S. population centers. Furthermore, the pasteurized milk sampling program reflects the radionuclides in milk received by at least 40 percent of the U.S. population.

A primary function of the milk program is to obtain current radionuclide concentrations in milk and determine long-term trends. Monthly samples are analyzed for I-131, Ba-140, Cs-137, and potassium. On a less frequent schedule but at least annually, Sr-89, Sr-90, H-3, I-129, stable I-127, C-14, plutonium, and uranium are determined.

2.2 Air Program

The ERAMS Air Program consists of 67 sampling locations (see Fig. 2.2-1). Each location submits to EERF particulate filters obtained from continuous sampling in which filters are changed twice a week, and samples of precipitation as it occurs. We estimate that the air sampling program reflects the air particulates and precipitation exposure received by 30 percent of the U.S. population.

A gross beta analysis is performed on each air filter and on a aliquot of each composited monthly precipitation sample. A gamma scan is performed on air filters if the gross beta in air exceeds 1 pCi per cubic

Figure 2.1-1. Pasteurized milk sampling sites

Figure 2.2-1. Air and precipitation sampling sites

meter and on precipitation samples if the gross beta in water exceeds 10 pCi per liter. Precipitation samples are also analyzed for tritium, and a composite of the March through May samples is analyzed for plutonium and uranium each year. Quarterly composites of the air particulate filters are analyzed for plutonium and uranium. On a semiannual basis, dry compressed air samples are purchased at 12 locations from commercial air suppliers and shipped to EERF and analyzed for Kr-85 (see Fig. 2.2-2).

2.3 Drinking Water Program

Quarterly grab samples are taken at 78 sites that represent the drinking water of major population centers (see Fig. 2.3-1). These samples are analyzed quarterly for tritium and annually for gamma, gross alpha, gross beta, radium, strontium, plutonium, uranium, and iodine.

2.4 Surface Water Program

Surface water grab samples are collected quarterly at 58 locations (see Fig. 2.3-2). These samples are obtained from surface water sources located near the first point of public use downstream of major nuclear facilities that are present or potential sources of drinking water to large populations. These samples are analyzed quarterly for tritium and gamma scanned annually in the spring to measure radionuclide washout from the atmosphere.

Figure 2.2-2. Krypton-85 sampling sites

Figure 2.3-1. Drinking water sampling sites

Figure 2.3-2. Surface water sampling sites

3.0 DOSIMETRY AND RISK ANALYSIS FROM THE ERAMS DATA BASE

3.1 Structure and Function of the ERAMS Data Base

ERAMS is structured to aid in assessing individual and collective dose and risk to populations. The ERAMS data base provides EPA the ability to assess the hazards technologically enhanced radiation levels (such as industrial operations that elevate environmental radiation levels) and short-term regional or global impact (such as waterborne unplanned release events and atmospheric fallout episodes). Concentrations are measured through human receptor pathways and, ultimately, dose and health impact are calculated. This capability is a distinctive feature of the ERAMS network and its associated technical support.

3.2 ERAMSDOSE and Computer Program

The methodology for analyzing ERAMS data may be applied to assess short-term events or persistently elevated environmental concentrations of radionuclides. The steps in performing a dose assessment are as follows:

1. The assessment location(s), time interval, and sample media are defined.
2. Concentrations for each sample type and location are generated. This may be done either on a gross activity basis or by employing a background subtraction procedure to remove ambient concentrations from the gross values. At this point the analysis, plots or colors graphical displays may be produced to show the time dependency of the measured levels. These data are passed to the next step for calculation of dose and risk values.

3. Next, media concentrations integrated over time are calculated from the concentration profiles. These are used to estimate inhalation or ingestion of radionuclides by people.
4. Data on the time-integrated activity for each exposure pathway are then used with an environmental pathways model to calculate the movement of the radionuclides to human receptors.
5. Dose equivalent and risk factors are then applied in these ERAMS assessments. Dose equivalent factors are based on state-of-the-art dosimetry, and risk factors are obtained from current version of the RADRISK (Du80) computer code.

3.3 Dose and Health Risk Assessment Obtained from a Single Measurement

Instances of samples with atypically high concentrations as measured by ERAMS generally fall into one of two categories. Sampling may be raised above ambient levels for an extended period such as following an atmospheric fallout event or a single sample may be atypically high, as that obtained from a quarterly river sample. This section presents an example of how an assessment may be made of a single atypically high measurement using the ERAMS dosimetry and health risk methodology.

Past examples of such assessments include estimation of health impacts of the radionuclides from volcanic ash, response to specific State Health Department requests for sample analysis, and calculation of dose and health risk from uranium, thorium and radium in drinking water. The specific example presented below is for a water sample collected at Rulo, Nebraska in 1980 by the surface water network of ERAMS.

3.3.1 Surface Water Sample: Rulo, Nebraska

The quarterly surface water grab sample had a measured Co-60 concentration of 22 pci/liter. We assumed that the measured Co-60 concentration persisted for 6 months. (3 months previous to and 3 months subsequent to the collection). ICRP Publication 23 (ICRP75) gives a daily fluid intake of 1.95 liters (2 liters was used for this calculation) with almost all the fluid intake being from tap water and water based drinks. Therefore, an individual is assumed to ingest 8000 picocuries of Co-60 in 6 months (22 pci/l · 2 l/day · 182.5 days). The calculation is conservative because all Co-60 is assumed to be in the soluble form and all the fluid intake for six months is assumed to contain Co-60 at a concentration of 22 pCi/l.

Dose equivalent and risk factors for Co-60 (see Table 3) were obtained using the RADRISK computer code (Du80). Committed dose equivalents in target organs due to the ingestion of 8000 pCi of Co-60 were used to calculate the weighted mean committed dose equivalent. We calculated "weighted mean" dose equivalents by using organ dose equivalent weighting factors developed by EPA and summing the results (See Table 4).

Table 3

Co-60 70 Year Dose Equivalent Rates Due to a Lifetime Ingestion at a Rate of 1.0 Picocurie Per Year (f_1 = 5.0E-02 = fraction from GI tract that goes to blood)

Target Organ	70-year Dose Equivalent Rate (mrem/yr)
Red Marrow	5.37E-06
Endosteal	3.92E-06
Pulmonary	2.75E-06
Breast	4.20E-06
Liver	8.53E-06
Stomach Wall	5.34E-06
Pancreas	6.03E-06
LLI Wall	4.02E-05
Kidneys	5.74E-06
Bladder Wall	6.15E-06
ULI Wall	2.03E-05
SI Wall	1.21E-05
Ovaries	1.24E-05
Testes	3.73E-06
Spleen	5.00E-06
Uterus	1.05E-05
Thymus	5.61E-06
Throid	3.01E-06
Total (Somatic)	

Table 4

Committed Dose Equivalent in Target Organs Due to the Ingestion of 8000 Picocuries of Co-60 and Organ Dose Equivalent Weighting Factors Used to Calculate the Weighted Mean Committed Dose Equivalent

Target Organ	Committed Dose Equivalent (mrem)	Weighting Factor
Red Marrow	4.3E-02	0.15590
Endosteal Cells	3.1E-02	0.01470
Pulmonary	2.2E-02	0.29080
Breast	3.4E-02	0.19080
Liver	6.8E-02	0.07460
Stomach Wall	4.3E-02	0.04150
Pancreas	4.8E-02	0.05810
LLI Wall	3.2E-01	0.03320
Kidneys	4.6E-02	0.01660
Bladder Wall	4.9E-02	0.01660
ULI Wall	1.6E-01	0.01660
SI Wall	9.7E-02	0.00830
Ovaries	1.0E-01	0.00830
Testes	3.0E-02	0.00830
Spleen	4.0E-02	0.00830
Uterus	8.4E-02	0.00830
Thymus	4.5E-02	0.00830
Thyroid	2.4E-02	0.04050
Weighted mean	4.8E-02	

The weighting factors for each target organ represent the proportion of the fatal cancer risk resulting from low LET irradiation of the target organ to the total fatal cancer risk when the whole body is irradiated uniformly. The method of summing weighted organ dose equivalents is similar to the approach introduced by the ICRP in publication 26 (ICRP77) and subsequently designated the effective dose equivalent in publication 28 (ICRP78). The EPA weighting factors were developed for a general public exposure situation, whereas the ICRP weighting factors are for an occupational exposure situation.

The Co-60 fatal cancer risk coefficients shown in Table 3 are based on an ingestion intake existing for the cohort lifetime (71 years average lifetime expectancy). Therefore, calculated individual risk will be approximate since the intake only exists for 6 months and not a lifetime. The actual risk will also depend on the age of individual when the Co-60 was ingested. With these limitations in mind, we calculated an additional lifetime fatal cancer risk of 1.4E-08 to an individual in the population who ingests 8000 picocuries of Co-60.

$$\frac{\text{risk}}{\text{yr}} = 8000 \text{ pCi} \cdot \frac{1.24\text{E-}05 \text{ fatal cancers}}{10^{5} \text{ persons} \cdot \text{pCi/yr} \cdot 71} = 1.4\text{E-}08$$

For perspective, this calculated fatal cancer risk is 9.3E-06 percent of the American Cancer Society estimated risk of cancer death from all causes of 0.15 (Ba79). Therefore, we concluded that the observed level of Co-60 in the Rulo, Nebraska water sample does not consitute a significant health risk. Subsequent radiochemical analysis on the water sample indicated

that essentially all the Co-60 activity was contained in the sediment and not in the soluble fraction. Therefore, even the very low calculated individual fatal cancer risk of 1.4E-08 is probably somewhat high. The capability to analyze such releases serves to avoid unwarranted public concern and also maintains the technological ability to evaluate larger and more serious releases. In addition to the analyses of regional events as described above, the ERAMS data base has also been used to evaluate large scale short-term releases to the environment.

3.4 Chinese Nuclear Test, September 1976

Following atmospheric weapon tests in September and November of 1976, EERF personnel examined the ERAMS data that had been collected and analyzed the U.S. population doses received from ^{131}I via the milk pathway. This nuclide and pathway were shown in this and earlier studies to be critical in terms of dose received. The results of this analysis were summarized and published in Science (Sm78). The analysis performed for this event was based on hand calculations of summaries of radionuclide concentrations obtained from the computer data base. At that time, there was no comprehensive methodology for calculating doses and health risk from all relevant environmental pathways. This limitation demonstrated the need to develop a more complete computer-based calculational method. Personnel at the EERF developed this needed methodology during 1977 and 1978 and first applied it to the data obtained from the Chinese atmospheric test of September 1977.

3.5 Chinese Nuclear Test, September 1977

This Chinese nuclear weapons test also resulted in increased environmental radionuclide concentrations in the United States. The ERAMS network again recorded increased radioactivity in airborne particulates and in the pasteurized milk network. The buildup and depletion of activity in daily measurements of airborne particulates are shown in Figs. 3.3-1 through 3.3-6 for the dates 9/23/77 through 10/14/77. The corresponding buildup and depletion of ^{131}I in pasteurized milk are shown in Figs. 3.3-7 through 3.3-14 for the dates 9/25/77 through 12/31/77. The ERAMSDOSE computer program that had been developed previously was used to calculate dose and health risk resulting from this nuclear test. The application of this methodology is outlined in the following sections.

3.5.1 Dose Estimates for Individuals

Maximum* committed dose equivalent to individuals for eight organs was calculated for each state.

Equations. The equation used for the individual dose calculations is

$$ID_{sao} = \sum_{n=1}^{9} \left\{ \left[\sum_{p=1}^{2} (C_{psn})\,(IR_{pa})\,(DCF_{pnao}) \right] + 24\,(C_{3sn})\,(DCF_{3nao}) \right\} \quad \text{(Eq. 1)}$$

where

a = summation index for age group (4 age groups)

n = summation index for nuclide (9 nuclides)

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*Since the pasteurized milk samples are composited from several milk supplies in a state, it is possible that higher doses could have been calculated for an individual who drinks milk from a single dairy or who drinks unprocessed milk from a single farm. Also, it is possible that air concentrations of radionuclides could be higher at a location other than the sampling location(s) within a state.

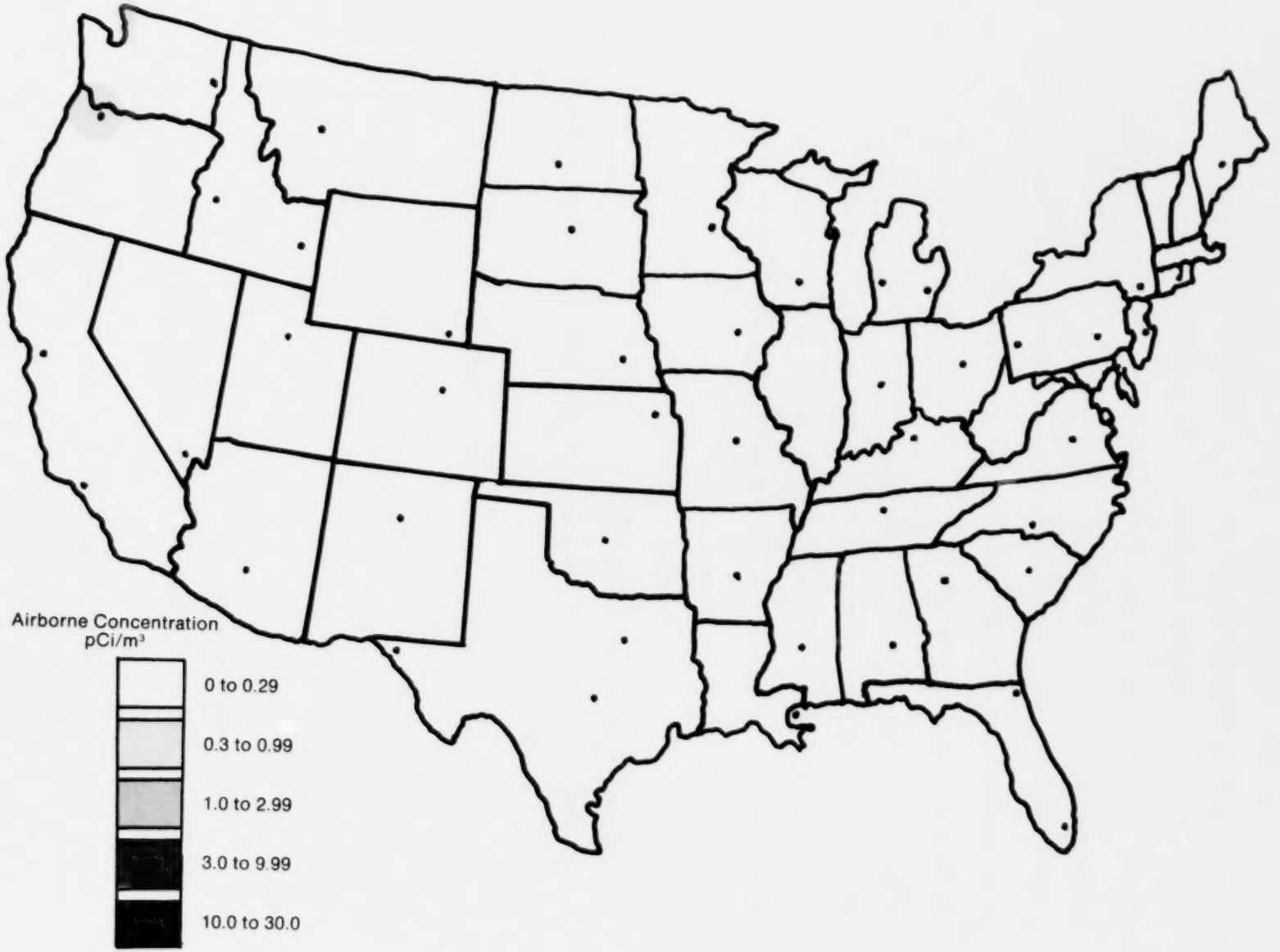

Fig. 3.3-1. Gross beta in airborne particulates: September 23, 1977

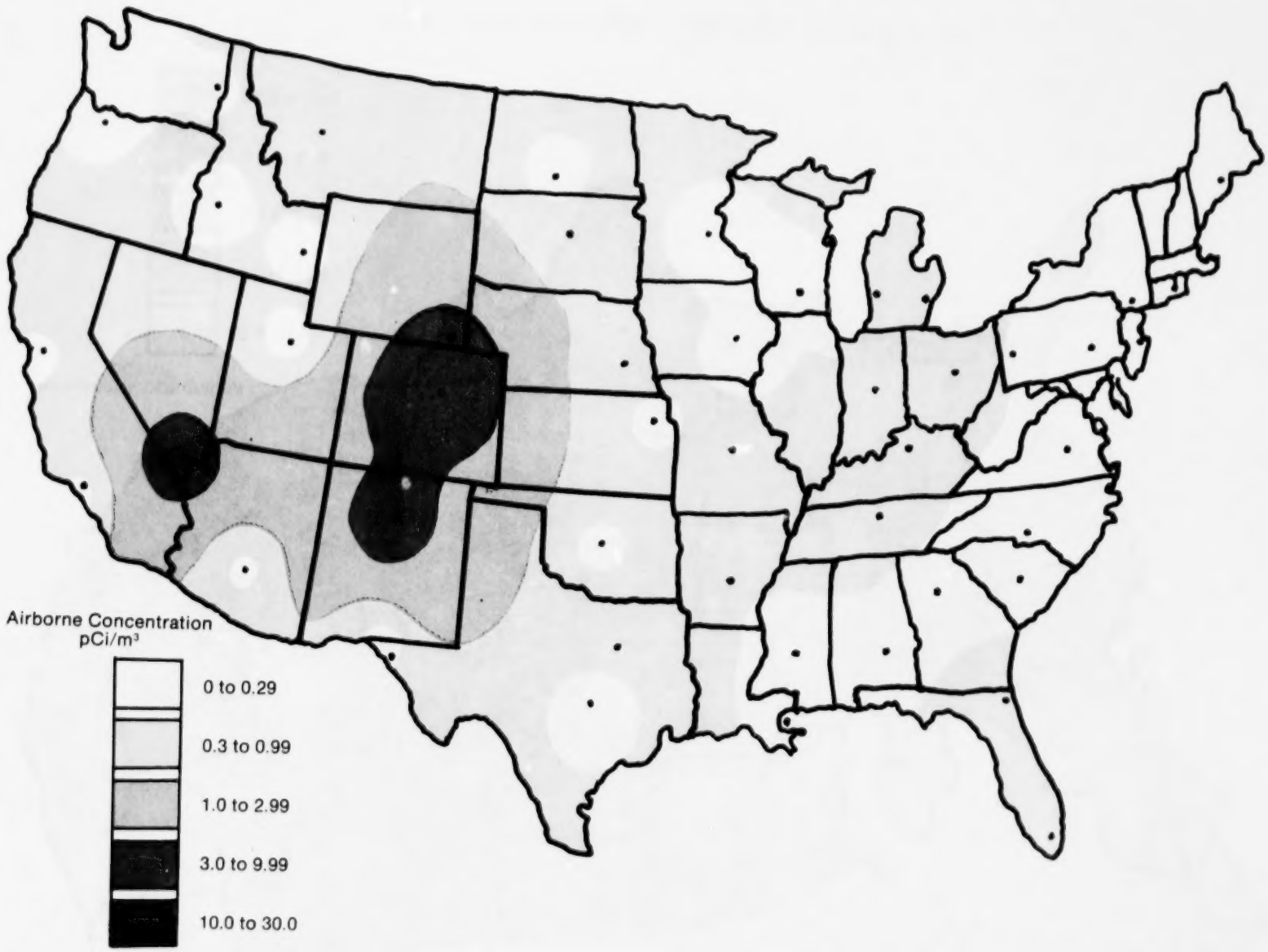

Fig. 3.3-2. Gross beta in airborne particulates: September 25, 1977

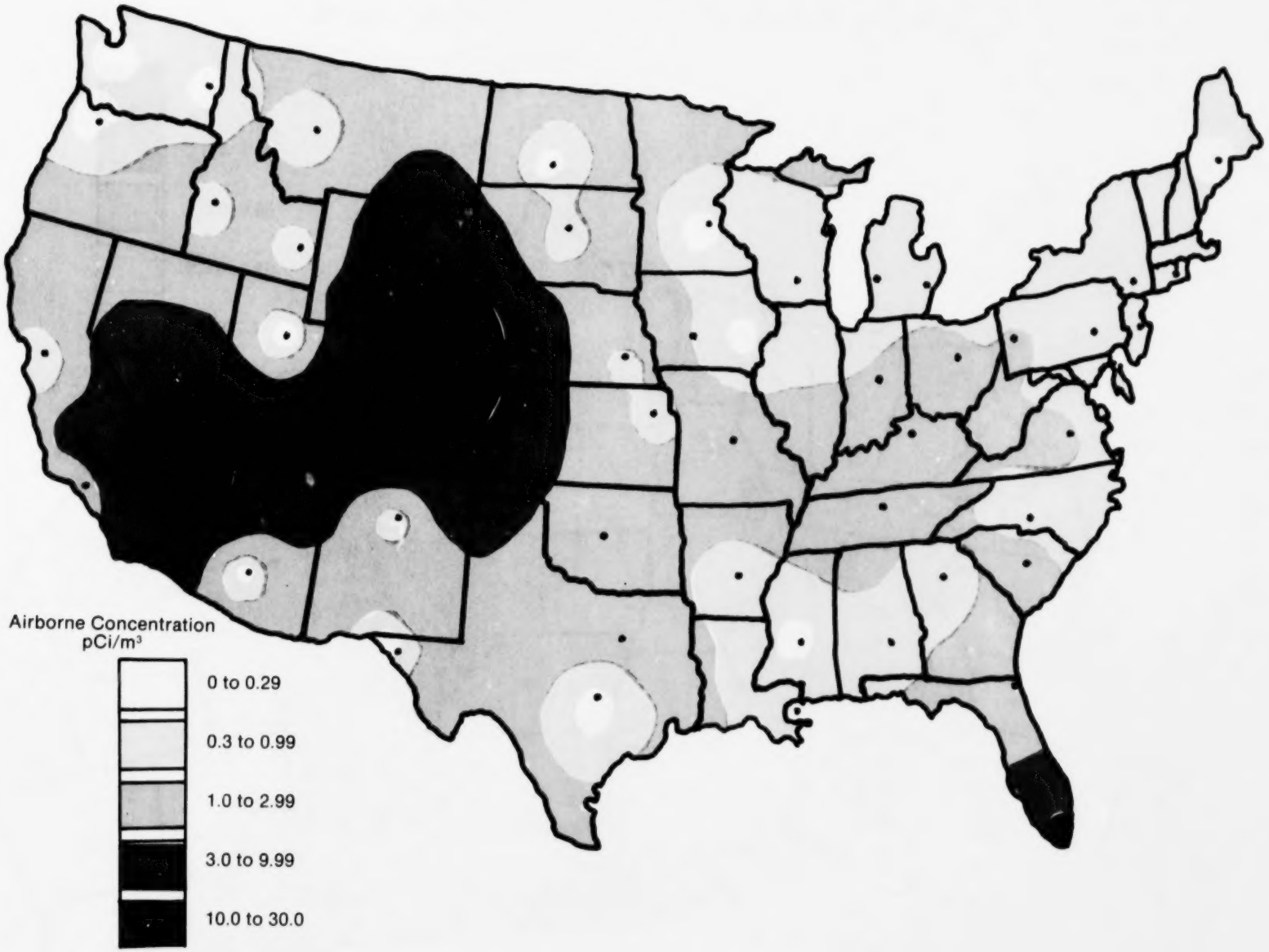

Fig. 3.3-3. Gross beta in airborne particulates: September 27, 1977

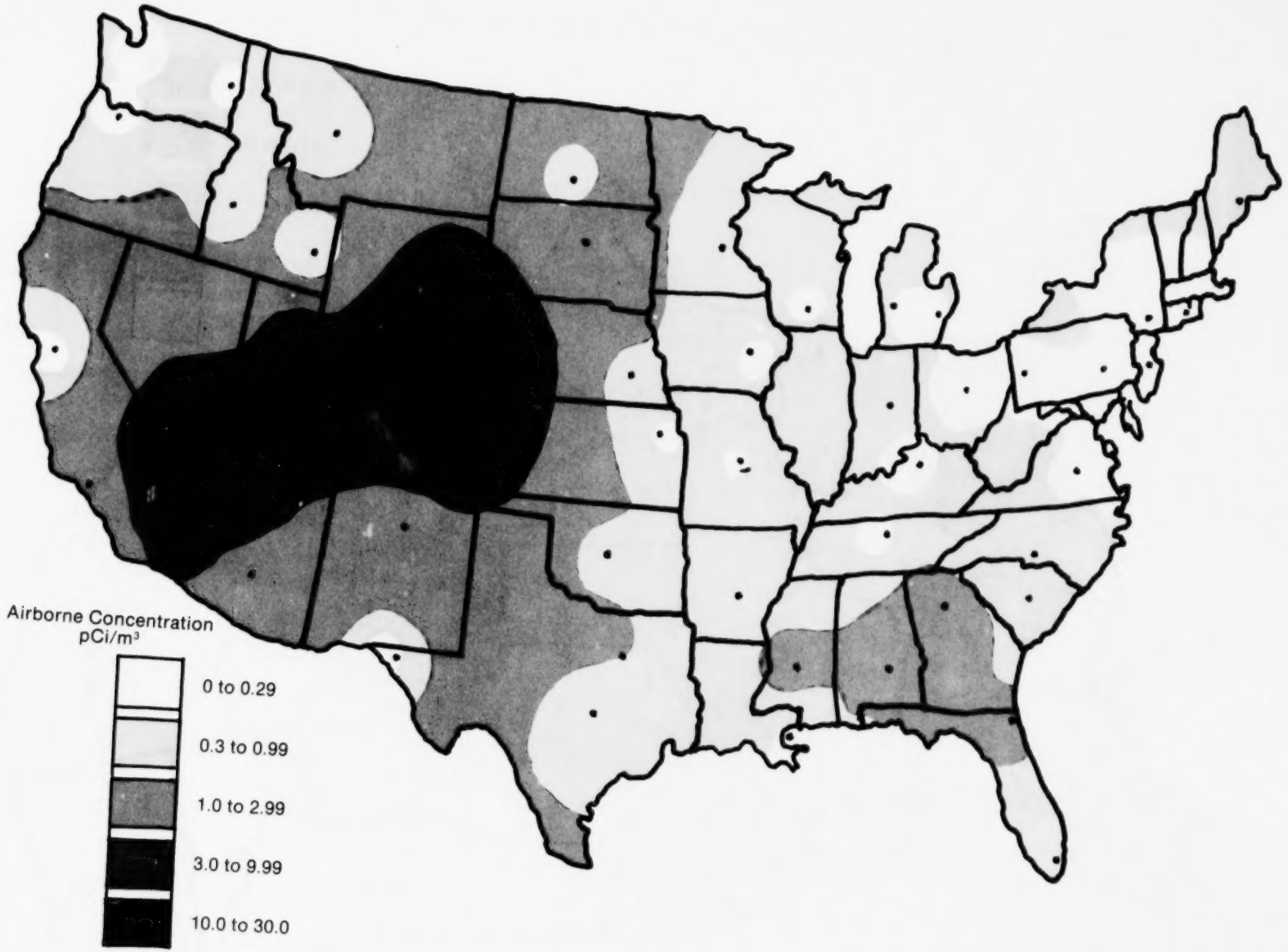

Fig. 3.3-4. Gross beta in airborne particulates: September 29, 1977

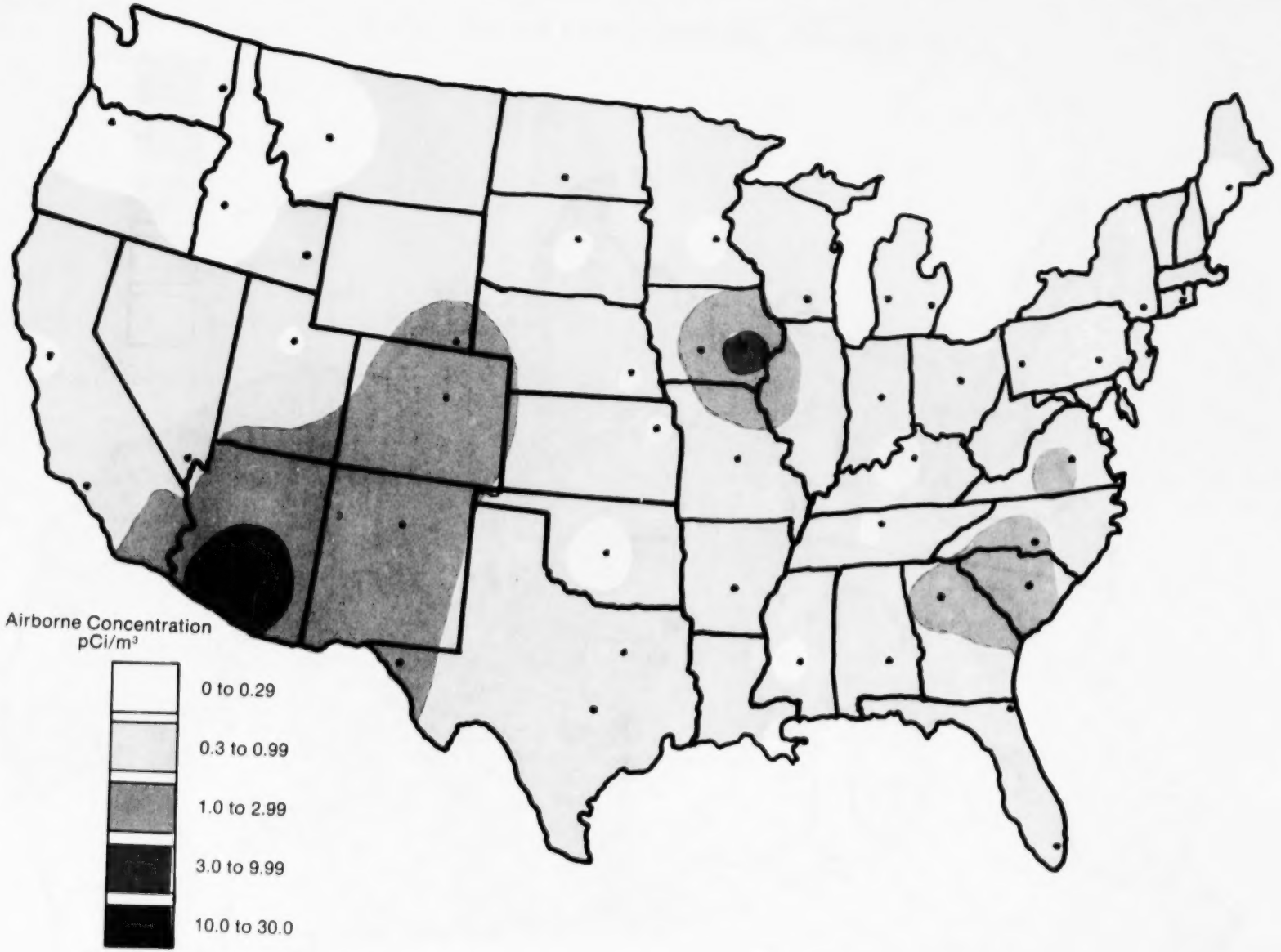

Fig. 3.3-5. Gross beta in airborne particulates: October 1, 1977

Fig. 3.3-6. Gross beta in airborne particulates: October 14, 1977

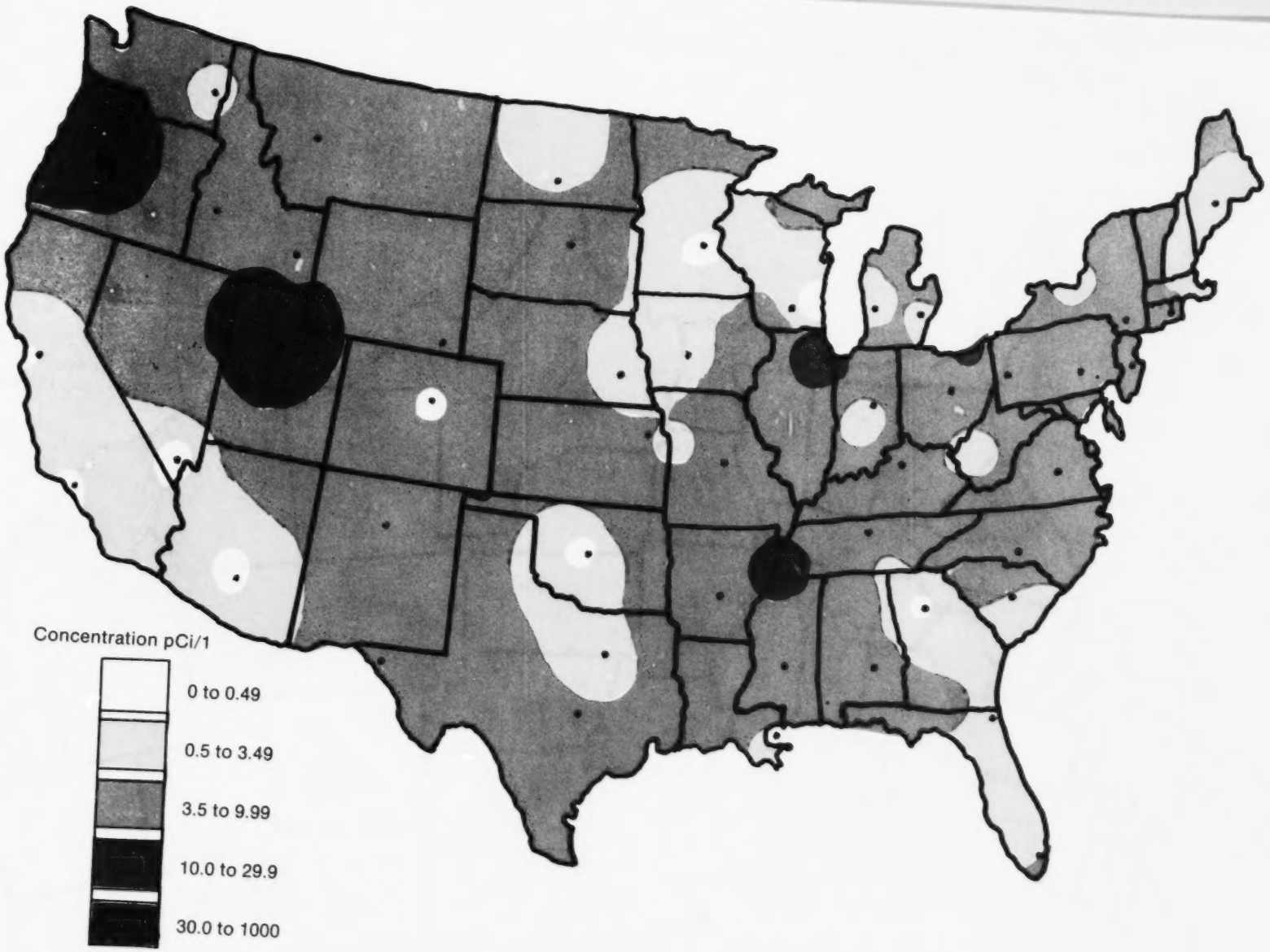

Fig. 3.3-7. I-131 in pasteurized milk: September 15 - October 1, 1977

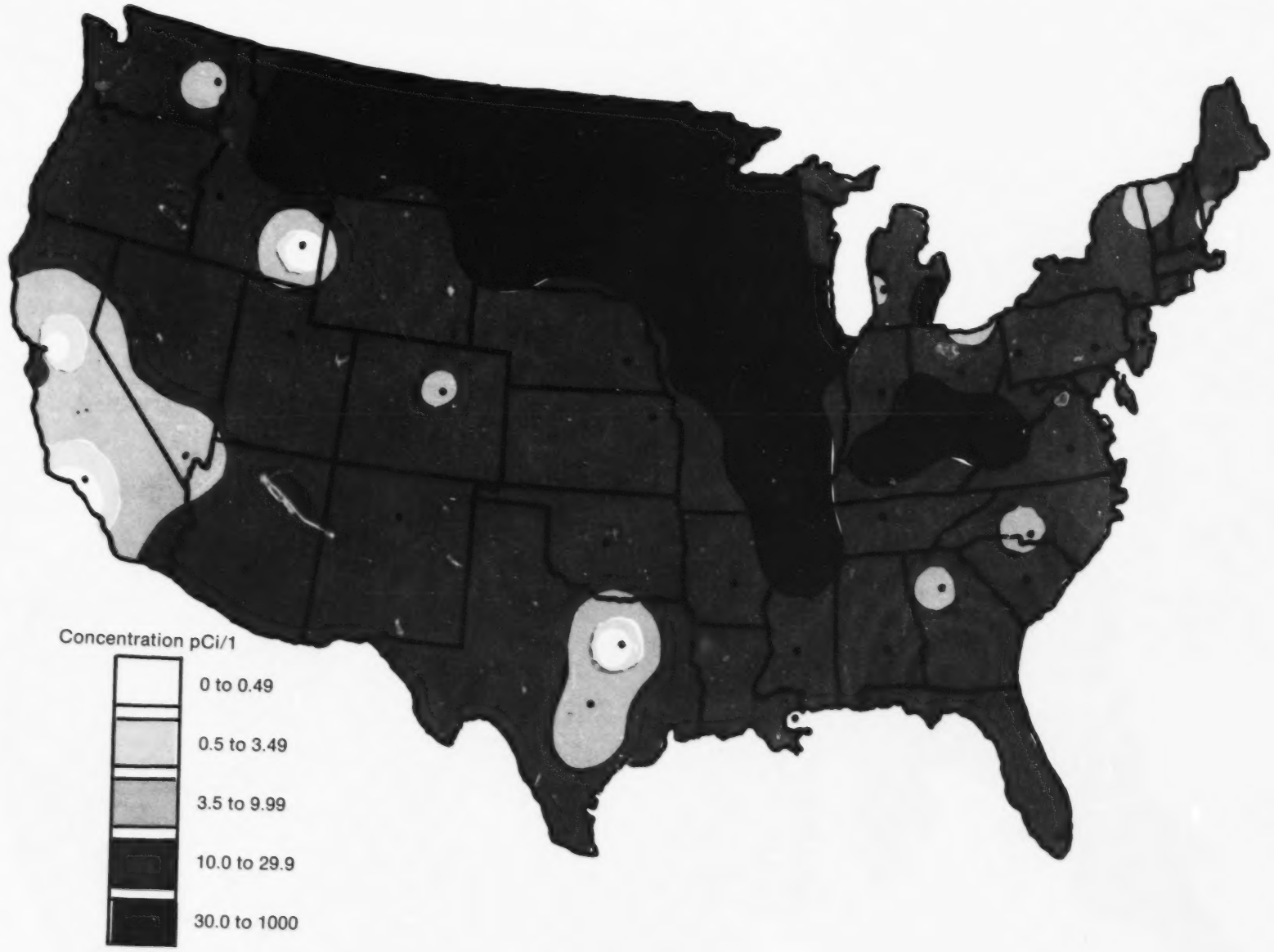

Fig. 3.3-8. I-131 in pasteurized milk: October 2 - October 8, 1977

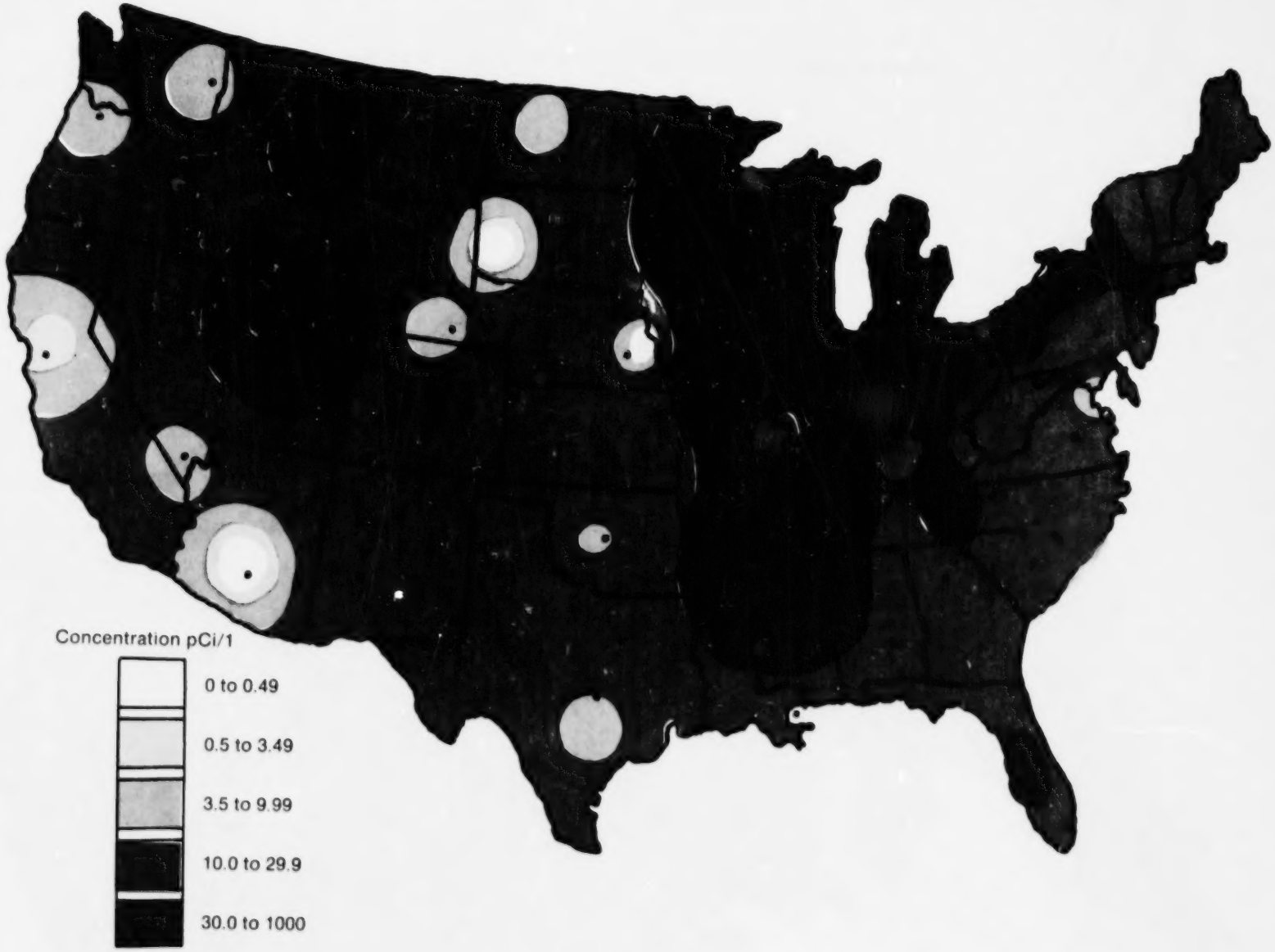

Fig. 3.3-9. I-131 in pasteurized milk: October 9 - October 15, 1977

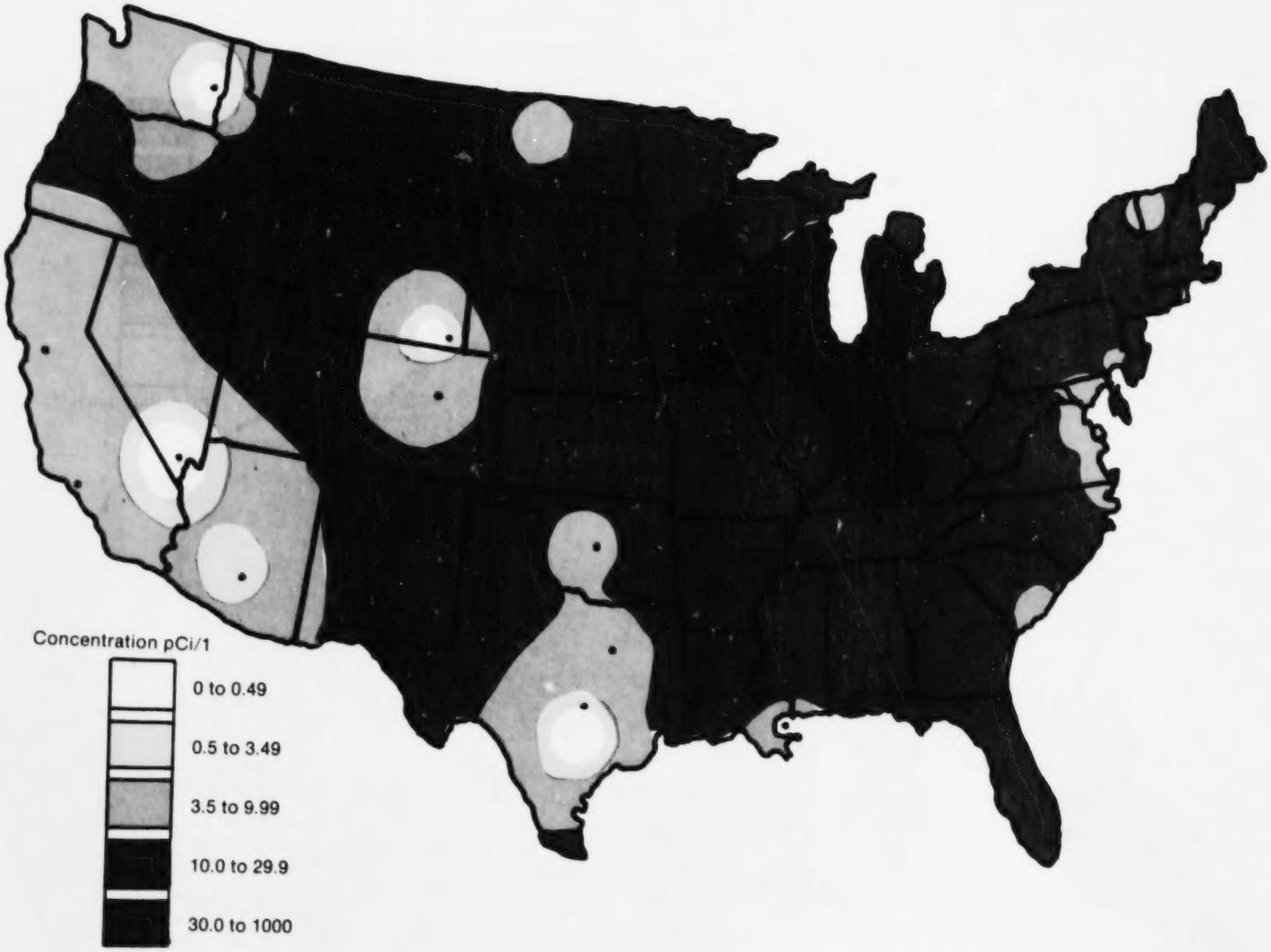

Fig. 3.3-10. I-131 in pasteurized milk: October 15 - October 22, 1977

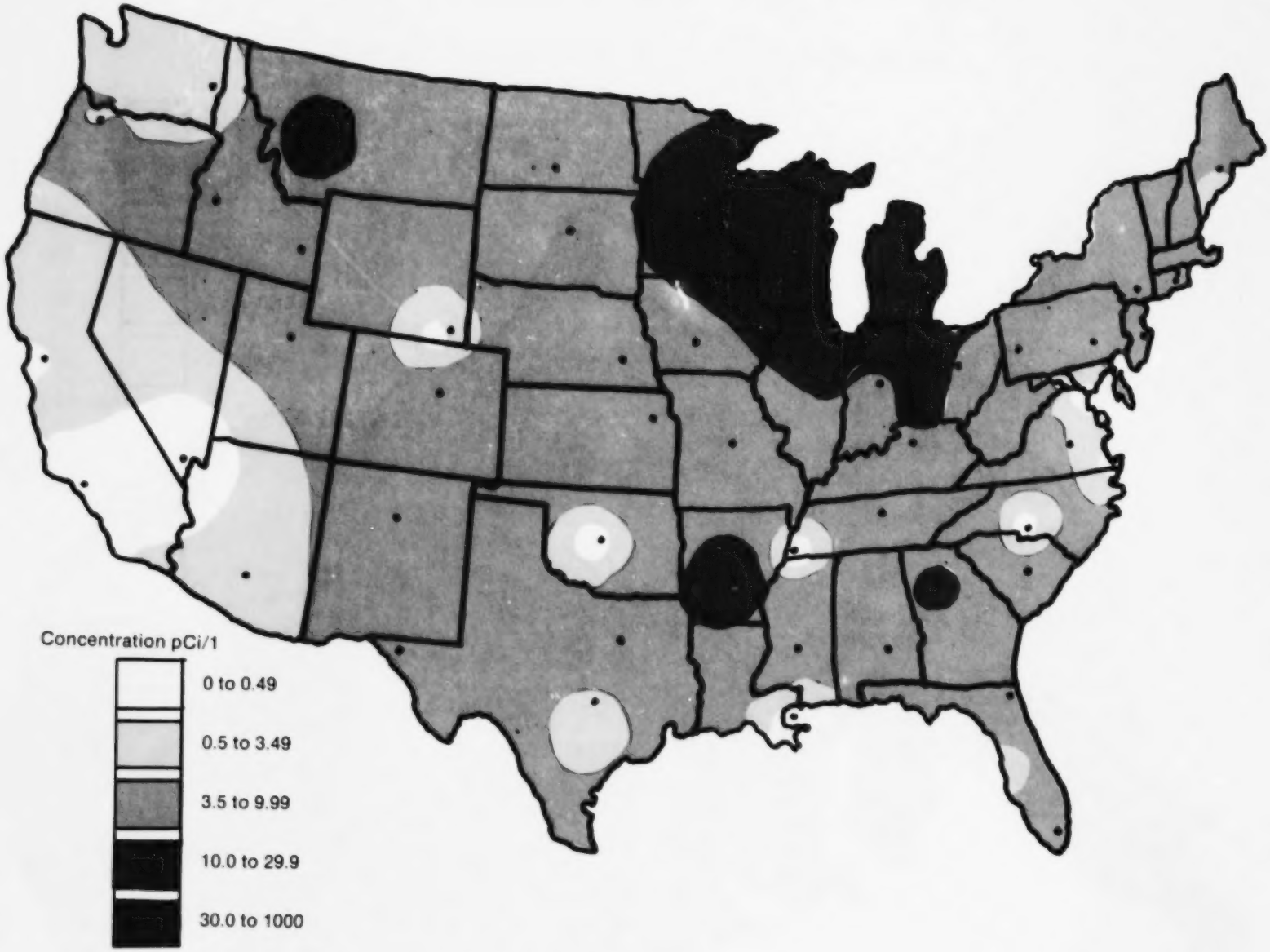

Fig. 3.3-11. I-131 in pasteurized milk: October 23 - October 29, 1977

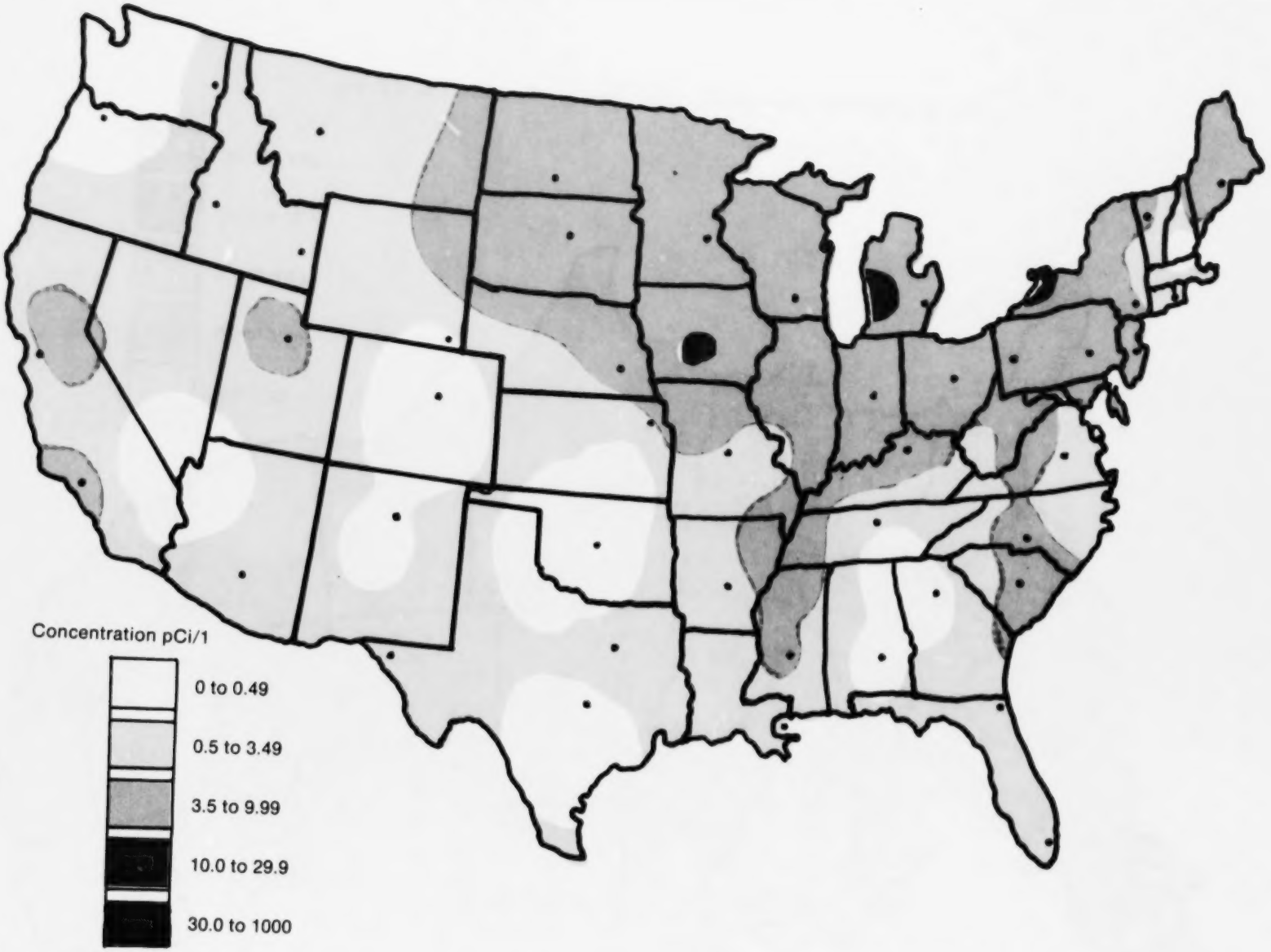

Fig. 3.3-12. I-131 in pasteurized milk: October 30 - November 5, 1977

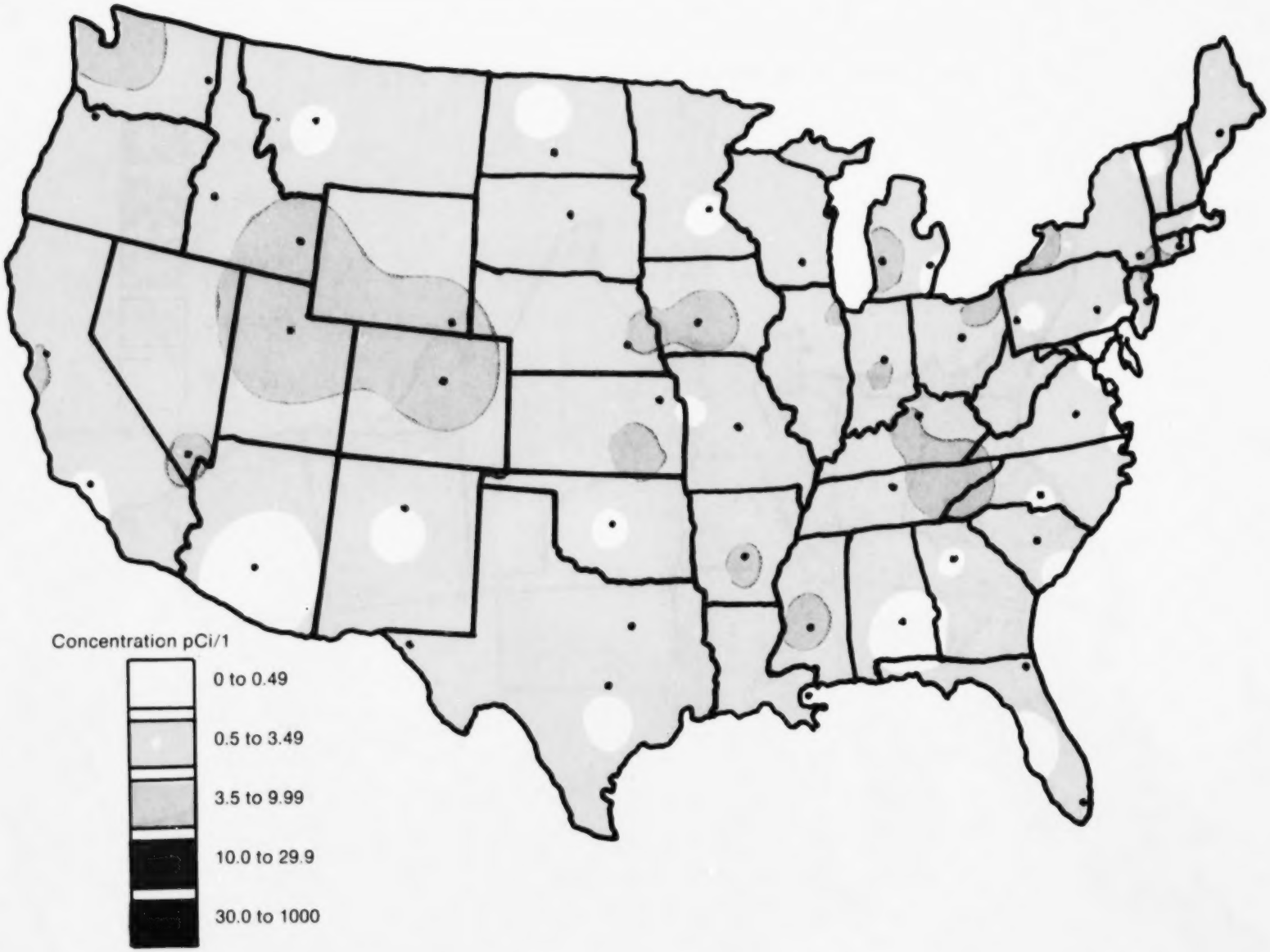

Fig. 3.3-13. I-131 in pasteurized milk: November 6 - November 30, 1977

Fig. 3.3-14. I-131 in pasteurized milk: December 12 - December 31, 1977

o = summation index for organ

p = summation index for pathway (1 for milk, 2 for air inhalation, 3 for air submersion)

s = summation index for state (51 states, including all states and the District of Columbia)

ID_{sao} = individual dose for integration period to organ o, for age group a in state s (mrem)*

C_{psn} = integrated radionuclide concentration for pathway p, state s, and nuclide n corrected to sample collection date (pCi-d/l for milk or pCi-d/m^3 for air)**

IR_{pa} = intake rate for pathway p and age group a (l/d for milk; m^3/day for air)

DCF_{pnao} = dose commitment factor*** for pathway p, nuclide n, age group a, and organ o (for milk and air inhalation mrem/pCi intake; for air submersion mrem/hr per pCi/m^3

24 = hours in one day

Milk pathway. The milk consumption rates for the individual dose calculations are the maximum listed in Table 125 of ICRP-23 (ICRP75) for that age group. After examining the data on radionuclide levels in pasteurized milk, it was obvious that radionuclide concentrations in milk

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*1,000 mrem equals 1 rem. The rem is the product of the absorbed dose (rads), an assigned quality factor, and other necessary modifying factors specific for the radiation considered.

**The curie (Ci) is a measure of radionuclide transformation rate. One Ci equals 3.7 x 10^{10} transformations per second. There are 10^{12} piocuries (pCi) per Ci.

***Dose commitment is the dose which will be delivered during the 50-year period following radionuclide intake.

started increasing in late September and were approaching background again by November 10. Thus an integration period of September 17 - December 1, 1977 (75 days) was chosen for the milk samples.

Inhalation pathway. The air inhalation rates for each age group are based on averaging* data given in ICRP-23 for that age group. There are large variations in breathing rates depending on age and amount of physical activity. The numbers used are based on 16 hours per day of light activity and 8 hours per day of rest, except for the infant. The infant breathing rate is based on 10 hours per day of light activity and 14 hours per day of rest.

A review of the radionuclide levels in air showed that the highest particulate concentrations occurred between September 17 and October 14. However, the precise integration periods for airborne radionuclides varied from station to station since the integrations were stopped five days after the radionuclide concentration in air had returned to near background levels.

Dose commitment factors. The dose commitment factors used for the internal dose calculations are an expression for the internal dose that will be delivered for a unit quantity of radionuclide ingested or inhaled. The dose factors used for external dose calculations are an

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*For the milk pathway, the maximum intake used in the calculations always occurs for the youngest age within the age group except for the infant for whom maximum milk consumption occurs at 6 months. The maximum breathing rate occurs for the oldest age within each age group. Since the largest contribution to individual doses from all pathways should result from ^{131}I in milk, it was decided to use the maximum milk consumption and the average air consumption to represent the critical receptor in each age group. This approach should be slightly conservative.

expression of the external dose rate per unit concentration of radionuclide in air. The dose factors for submersion are from the FESALAP report (AEC73) since they are not given in Regulatory Guide 1.109.

Integrated radionuclide concentrations in milk and air. The integrated milk and air concentrations* used in Eq. 1 were obtained by fitting a cubic-spline (Re67) to the radionuclide concentrations measured in ERAMS samples and numerically integrating the resulting curve, which expresses radionuclide concentrations vs. time. A representative curve for ^{131}I concentrations in milk at Anchorage, Alaska is shown in Fig. 3.3-15. A state average value was obtained by an arithmetic average of the data for each location in each state.

Discussion of calculated doses. The state average integrated concentrations are used with equation 1 to compute the individual doses discussed in this report. The maximum bone dose and lung doses are each approximately 25 percent of the maximum thyroid dose, and the maximum liver dose and kidney dose are each approximately 5 percent of the maximum thyroid dose. Thus the thyroid dose is dominant, but doses to bone and lung are within an order of magnitude of the thyroid dose.

3.5.2 Collective Dose Calculations

Collective dose is computed by summing the individual doses for all members of a population. It has units of persons times dose (person-rem).

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*Net concentrations for milk. Gross concentrations were used for air since background air concentrations of specific radionuclides are not available.

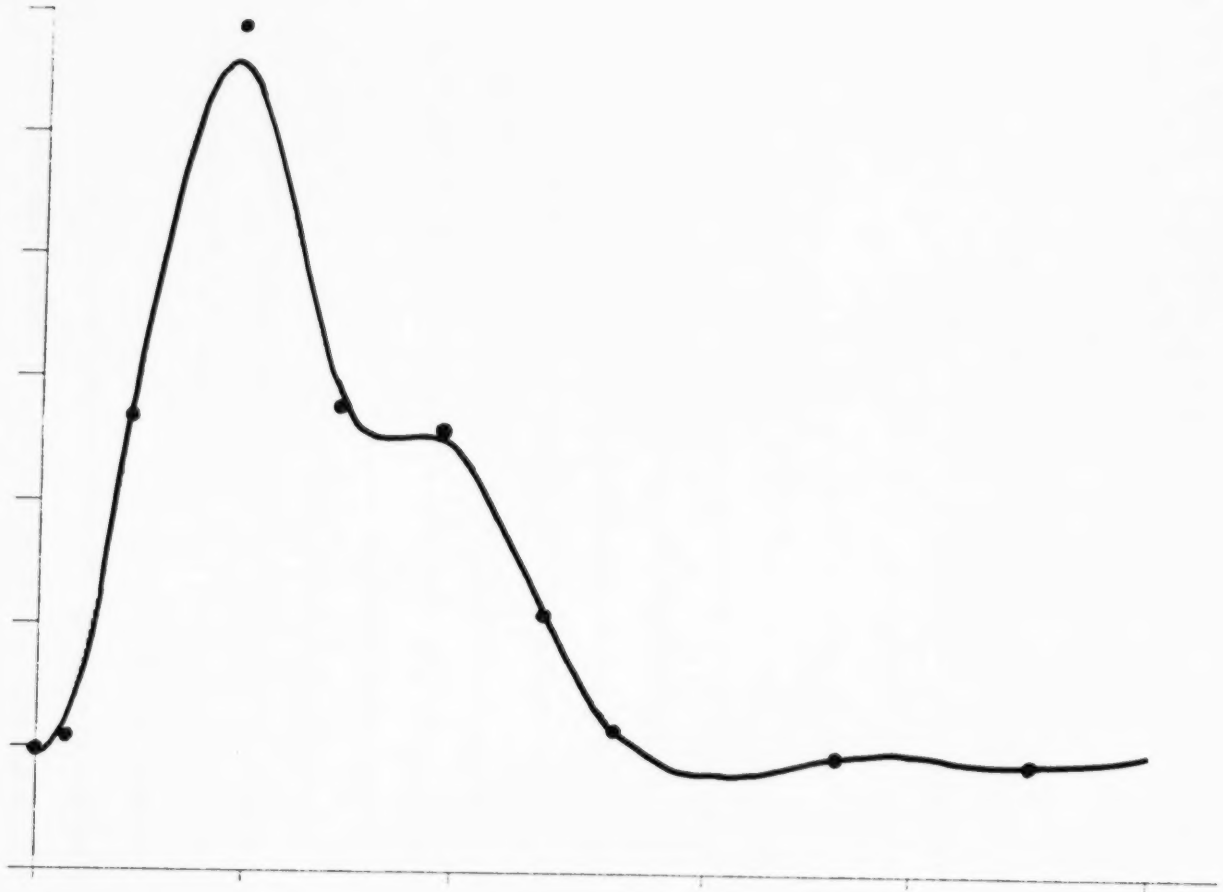


Fig. 3.3-15. Net 131-I concentration in milk - Anchorage, AK

Equation for collective dose. The equation used to calculate state collective dose for each organ is

$$PD_{so} = \sum_{n=1}^{2} \sum_{a=1}^{4} \left\{ \frac{(1000)\,(C_{1sn})\,(MC_s)\,(f_{1a})\,(DCF_{1nao})}{(n)\,(p)} \sum_{d=1}^{2} (f_d)\,(e^{-\lambda n t_d}) + (.001)\,(C_{2sn})\,(P_s)\,(f_{2a}) \left[(IR_{2a})\,(DCF_{2nao}) + (24)\,(PCF_{3nao}) \right] \right\} \quad \text{(Eq. 2)}$$

where:

PD_{so} = state collective dose to organ during the period September 17 - December 1, 1977 (man-rems)

1000 = conversion factor (lbs. - rem/Mlbs.-mrem)

.001 = conversion factor (rem/mrem)

d = summation index for food group (2 food groups)

MC_s = total fluid milk and fluid milk products consumed in state during integration period (Mlbs. consumed or committed for consumption)

f_d = fraction of milk used for food group d (dimensionless)

f_{pa} = for milk, fraction of total milk consumption used by age group a; for air, fraction of total state population in age group a (dimensionless)

DCF_{pnao} = dose commitment factor for pathway p, nuclide n, age group a, and organ o (for milk, man-mrem/pCi ingested; for air inhalation, mrem/pCi inhaled; for air submersion, mrem/hr per pCi/m^3)

λ_n = radioactive decay constant for nuclide n (d^{-1})

t_d = time between sample collection and consumption (d)

D = days in period of integration for milk pathway

ρ = milk density (lbs/l)

P_s = population in state s (people)

C_{psn}, IR_{pa}, 24 and the indexes a, n, o, p, and s have the same definition as for the individual dose calculations, The first line of equation 2 is for collective dose from milk ingestion and the second line is for collective dose from air inhalation and submersion.

State milk and air concentrations. The pasteurized milk portion of the ERAMS network includes 65 sampling locations within the United States. Radionuclide concentrations in milk were measured for at least one sampling location in each state following the test.

The integrated milk and air concentrations of each nuclide at each location were obtained using a cubic spline and numerical integration techniques as discussed earlier. For states with only one sampling location, the integrated milk and air concentrations for that location were used for the entire state. For the states where there were no air sampling locations, air concentrations from a nearby location were used as an estimate of air concentrations in the state. For states with more than one sampling location, an arithmetic average of the data for the locations in the state was used. There is a limit to the accuracy of these calculations since it was assumed that one, or in a few cases two, three, or four, sampling locations represent an entire state.

The use of a single sampling location to represent milk consumed in each state is supported by the following:

(1) The milk samples are a weighted composite of milk from each major milk processor supplying an area. The samples represent locally consumed milk whether the processor obtained it from local or remote suppliers.

(2) Many processors supply the smaller cities and towns in a state as well as the metropolitan areas where these milk samples are taken.

The use of a single sampling location to represent air concentrations in each state is supported by considering the variability in the observed concentrations between stations. Even in instances of localized rainout, which lend to yield the sharpest contrast in measurements, within state variation is generally within the uncertainty of other parameters used in the calculation. Typically, fallout plumes are widely dispersed after travelling the great distance from the point of formation in China to the United States. Thus, the plume of media debris may cover several states when it enters the U.S., and large variations in radionuclide concentrations within a single state would not normally be expected.

Other data. The population for each state was estimated as of July 1, 1976, according to the 1978 edition of the Information Please Almanac (IPA77).

Calculated dose. Using the methods, equation, and data discussed, the population doses were calculated for each state. The lung, thyroid, and bone doses were the highest of the organ doses calculated. In general, lung doses were highest in populations west of the Mississippi River and in the Southeast. Thyroid doses were highest in the eastern section of the Midwest, in the northern portion of the Southeast, and in the

Northeast. The doses to the bone were highest in populations of eight states located primarily in the Northern United States.

The highest collective dose to the lung was 18,400 man-rem in California, while the highest collective dose to the thyroid was 14,000 man-rem in Illinois. The highest collective dose to the bone was 16,300 man-rem in Illinois. For the total U.S. population, the highest doses were 150,200 man-rem to the lung, 127,700 man-rem to the thyroid, and 107,600 man-rem to the bone. Doses to the other organs considered in these calculations were from one-fourth to one-tenth of these highest doses.

Projected health effects. Health effects were estimated for the thyroid, lung, and the total body (exclusive of lung and thyroid). It was estimated that about 17 cancers (10 fatal) might occur over the next 45 years as a result of this test (see Table 5). A comparison of these projected deaths with the deaths due to natural occurrence of cancers from all causes lends perspective to these calculations. In 1975, 365,700 persons in the U.S. died from all types of cancers (MVSR77). Assuming a constant death rate, a natural occurrence of 16,456,200 deaths from all types of cancer would be expected over a 45-year period. Thus, the excess death rate is about one extra death for every 1,600,000 deaths occurring from all types of cancer. It is also estimated that there might be 3 additional serious genetic effects to all succeeding generations of the U.S.

population as a result of this nuclear test. Considering the current incidence rate of serious genetic effects of 10.7 percent (NAS80), it is estimated that there might be about 23,000,000 serious genetic effects from all causes in the U.S. during the next 50 years.

TABLE 5

Health Effects Estimates for the U.S. Population for the Chinese Nuclear Test of September 17, 1977

Organ	Somatic health effects per million man-rem (EPA73, EPA77c)		Population dose estimate (man-rem)	Estimated somatic health effects during the next 45 years due to this test	
	Cancer	Death		Cancer	Death
Thyroid (I-131)	11*	1.1	1.11×10^5	1.2	.12
Thyroid (other than I-131	106	10.6	1.70×10^4	1.8	.18
Lung	50	50	1.50×10^5	7.5***	7.5***
Total body**	350	139	1.72×10^4	6.0***	2.4***
			Total estimated somatic health effects for this event	16.5	10.2

* This thyroid cancer estimate is approximately six times lower than the number used in EPA's previous analysis of health effects from nuclear weapons tests (EPA77a). The change is the result of two factors:
an increase in the plateau length, as a function of time, for expression of excess thyroid cancers for the 0-2 years old age group; and a factor of ten decrease in the cancer risk per person rad for I-131 since beta particles for I-131 were considered less carcinogenic than photon radiation.

** Exclusive of lung and thyroid health effects.

*** The time required for these effects to occur is the lifetime of the exposed population. However, the majority of these effects should be within the next 45 years.

3.6 Collective Dose from Ambient Radionuclide Concentrations

The basic structure of radiation dosimetry provides for calculation of doses to target organs from the summation of radioactive emissions from all nuclides considered. Futhermore, since each target organ has its own risk value, it is difficult to use collective organ dose as a measure of combined hazard from the radionuclides. In spite of these limitations, the authors felt that tabulation of some concise dosimetric information was appropriate. For this reason, collective organ doses from milk, air inhalation, and external exposure pathways were calculated and presented for the three year intervals 1973-1976 and 1976-1979 and the two year interval 1979-1981 (see Table 6).

TABLE 6

Collective and Indiviudual Doses from Milk Ingestion, Air Inhalation and External Exposure Pathways

Collective doses over intervals specified

Date Interval	Minimum Dose (man-rem)	Maximum Dose (man-rem)	Organ Receiving Maximum Dose
July 1973-June 1976	4.8×10^3 (Wyoming)	7.3×10^5 (New York)	Bone
July 1976-June 1979	3.3×10^3 (Nevada)	5.3×10^5 (New York)	Bone
July 1979-December 1981	8.9×10^1 (Alaska)	4.2×10^5 (New York)	Bone

Maximum individual dose over the intervals specified

Date Interval	(mrem)	Organ Receiving Dose
July 1973-June 1976	159 (Arkansas)	Bone
July 1976-June 1979	159 (Arkansas)	Bone
July 1979-December 1981	93 (Massachusetts)	Bone

4.0 OBSERVATIONS OF SHORT-TERM AND LONG-TERM ENVIRONMENTAL RADIOACTIVITY TRENDS

4.1 Short-Term Trends in Environmental Radioactivity

Examination of the data collected by the ERAMS program has shown short-term increases in radioactivity in several instances. One example is shown for ^{234}U and ^{235}U data for Lynchburg, Virginia (Figs. 4.1-1 and 4.1-2), compared with ^{238}U values for the same location. These data exhibit increases in atmospheric concentrations and also an increase in the ratios $^{234}U/^{238}U$ and $^{235}U/^{238}U$, which is characteristic of enriched uranium releases.

The monitoring site under consideration was near the Babcock and Wilcox fuel fabrication plant in Lynchburg. During 1973-1975, the monitoring station was on company property and was subsequently moved in 1975 to a point more representative of the airborne exposure to a typical individual within the population. Although the magnitude of the concentration at the receptor point was observed to decrease markedly when the sampler was moved, the characteric pattern typical of enriched uranium releases is still evident in the data from more recent years.

Another example of short-term increases in radioactivity was observed following atmospheric fallout events in 1976 and 1977. Network monthly average values for ^{131}I in pasteurized milk were clearly elevated following both these events (see Fig. 4.1-3). In contrast to the behavior of ^{131}I, the network averages for ^{137}Cs in pasteurized milk did not

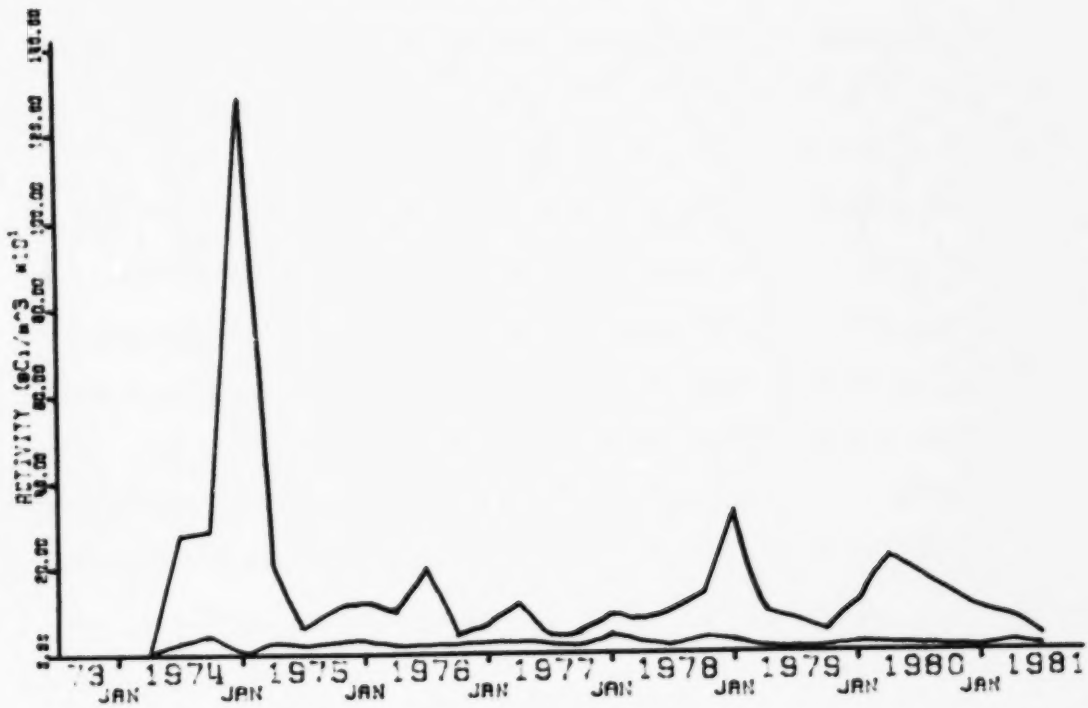
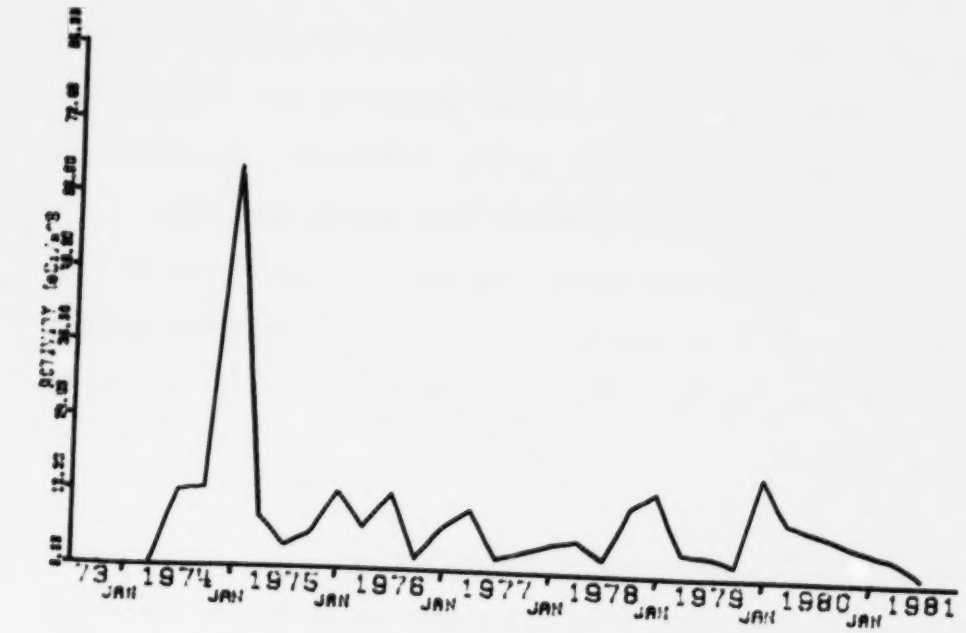


Fig. 4.1-1. U-234 and U-238 in airborne particulates--Lynchburg, VA



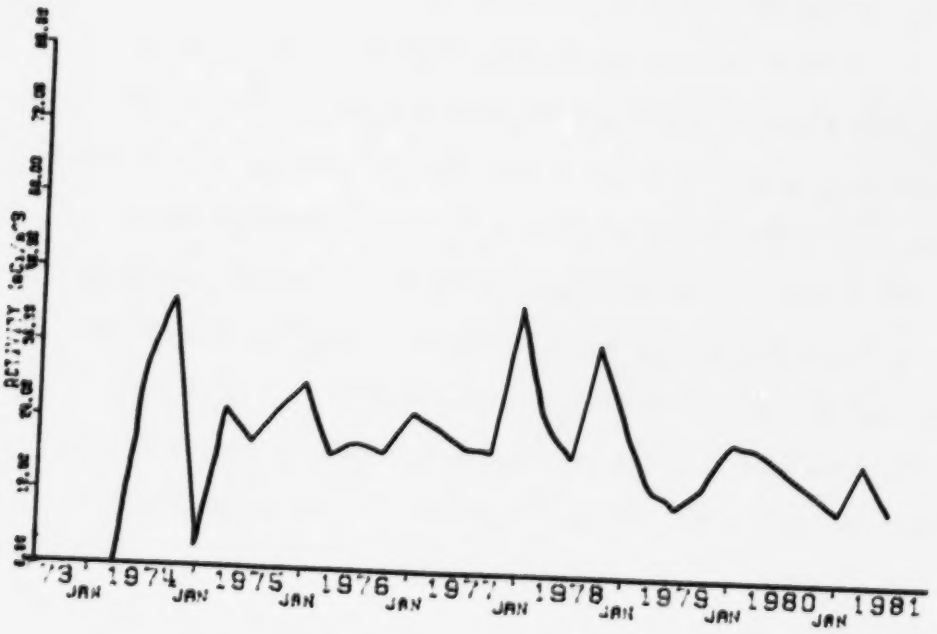


Fig. 4.1-2. U-235 and U-238 in airborne particulates--Lynchburg, VA

show the abrupt increases. Specific site meteorological conditions greatly affect washout from the contaminated atmosphere and, ultimately, the concentration observed in milk and surface atmosphere. This behavior is clearly observed following the Setpember 1976 episode when heavy rainfall over the Eastern United States resulted in sharply increased concentrations of I-131 in air and milk. The increased concentrations of I-131 in milk are shown in Fig. 4.1-5 for Hartford, Connecticut and 4.1-6 for Baltimore, Maryland.

4.2 Long-Term Trends in Environmental Radioactivity

Several types of data files contained within the ERAMS data base have recorded long-term trends in environmental levels. The expected increase in ^{85}Kr concentrations in the atmosphere due to nuclear fuel cycle operations (UNSCEAR77) has been observed (see Fig. 4.1-9). In addition, increased levels of ^{3}H have been observed in the waters of the Savannah River and the Tennessee River (Fig. 4.1-10), and in several drinking water supplies (Fig. 4.1-11). Nationwide average concentrations in surface streams are also shown in these figures to highlight the local variations.

When nuclear stations begin operating near an existing surface water station, the discharges of H-3 are recorded in the subsequent water samples. This effect is demonstrated clearly at the Doswell, Virginia site when the North Ana station began operation 5.5 miles upstream in 1978. The continual upward trend is clearly visible in Fig. 4.2-1.

The ERAMS data base also has recorded significant decreases in some environmental radioactivity. Since the period of numerous worldwide

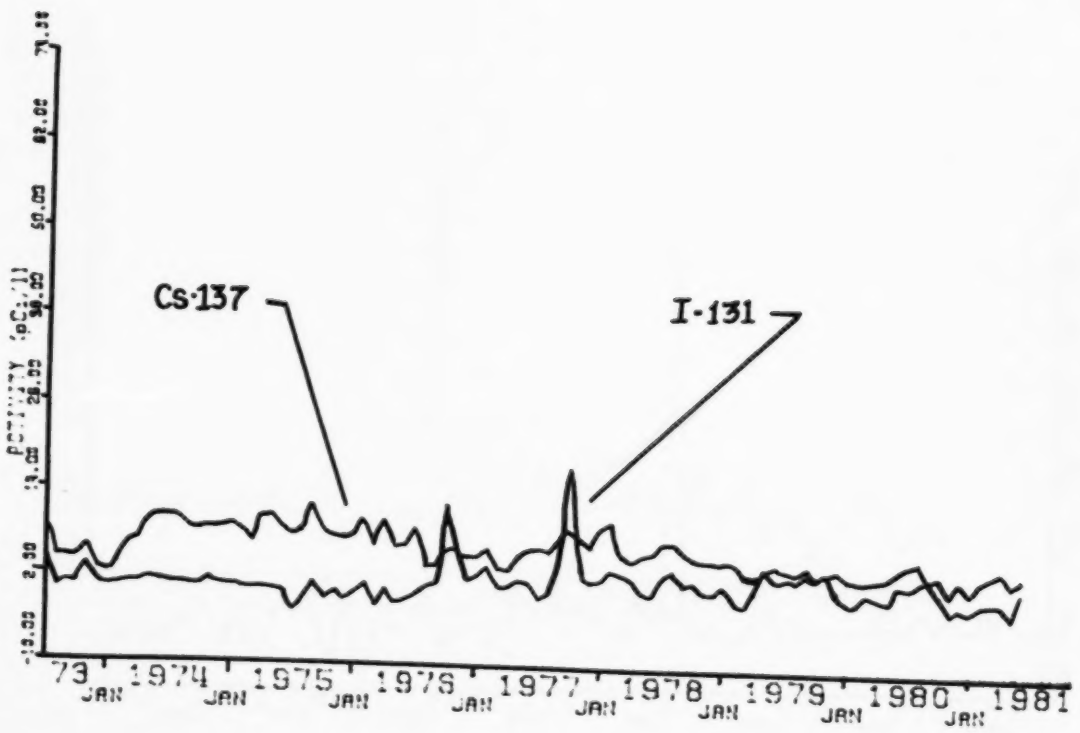


Fig. 4.1-3. I-131 and Cs-137 (pCi/Liter) in pasteurized milk--network averages

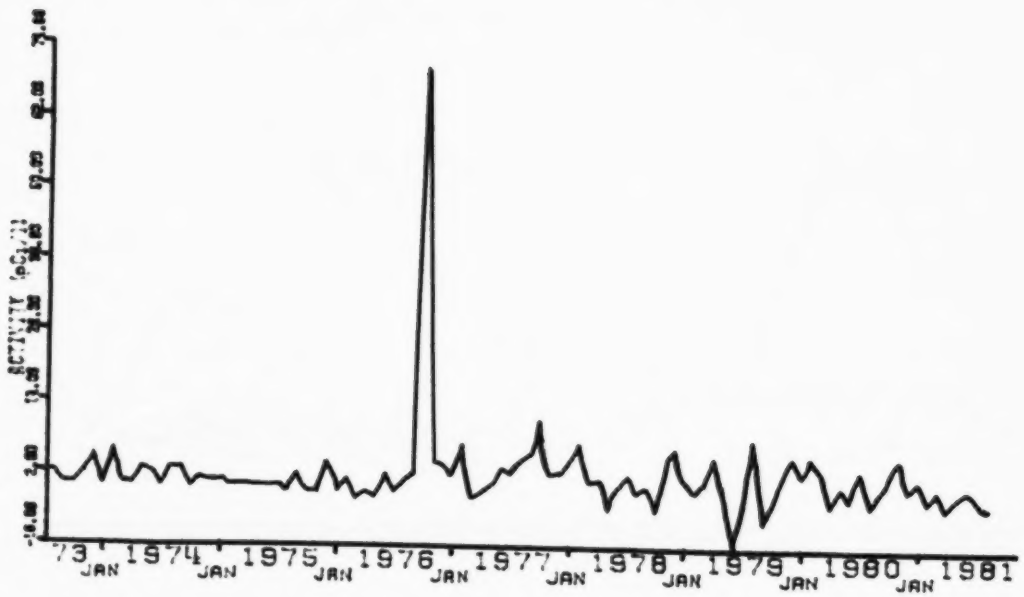


Fig. 4.1-4. I-131 (pCi/Liter) in pasteurized milk--Hartford, CT

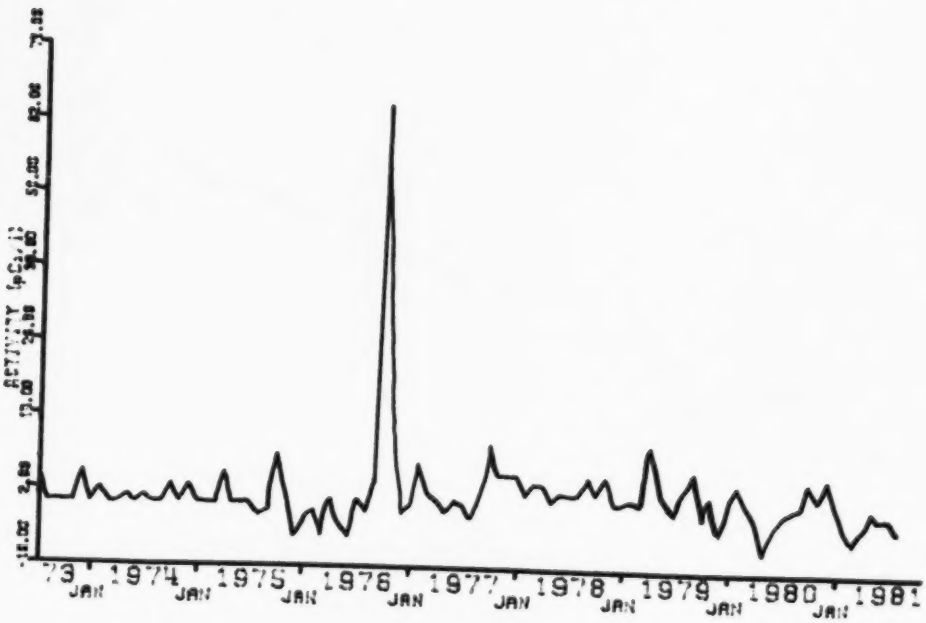


Fig. 4.1-5. I-131 in pasteurized milk--Baltimore, MD

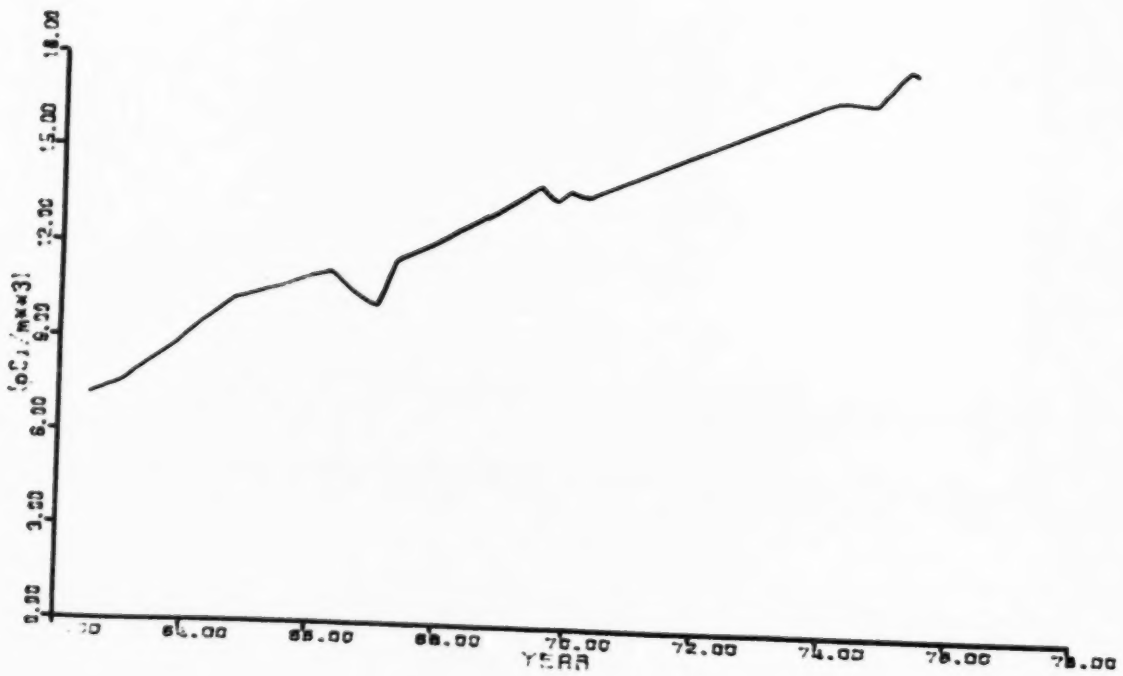
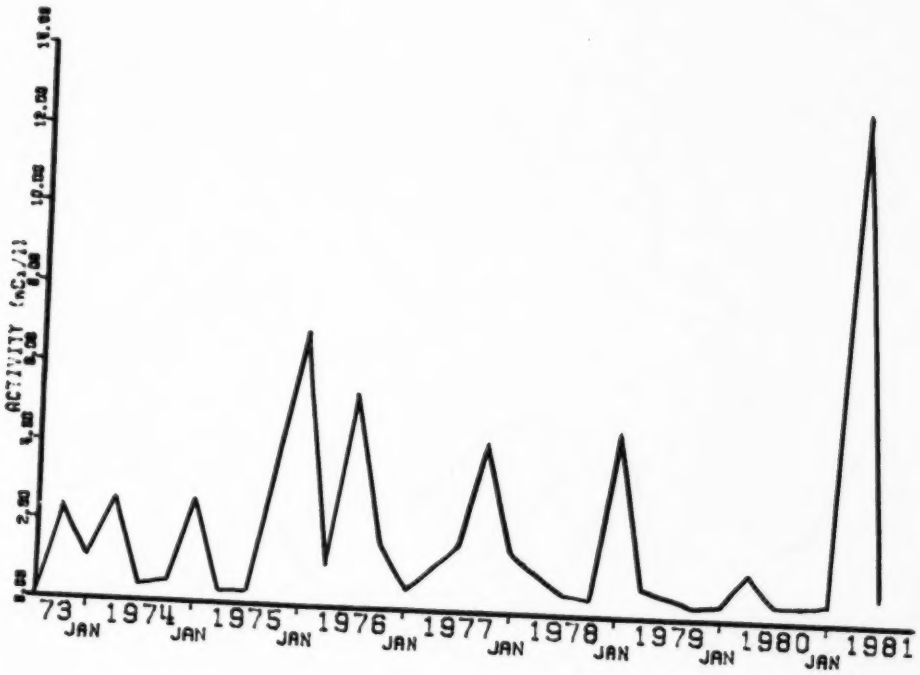
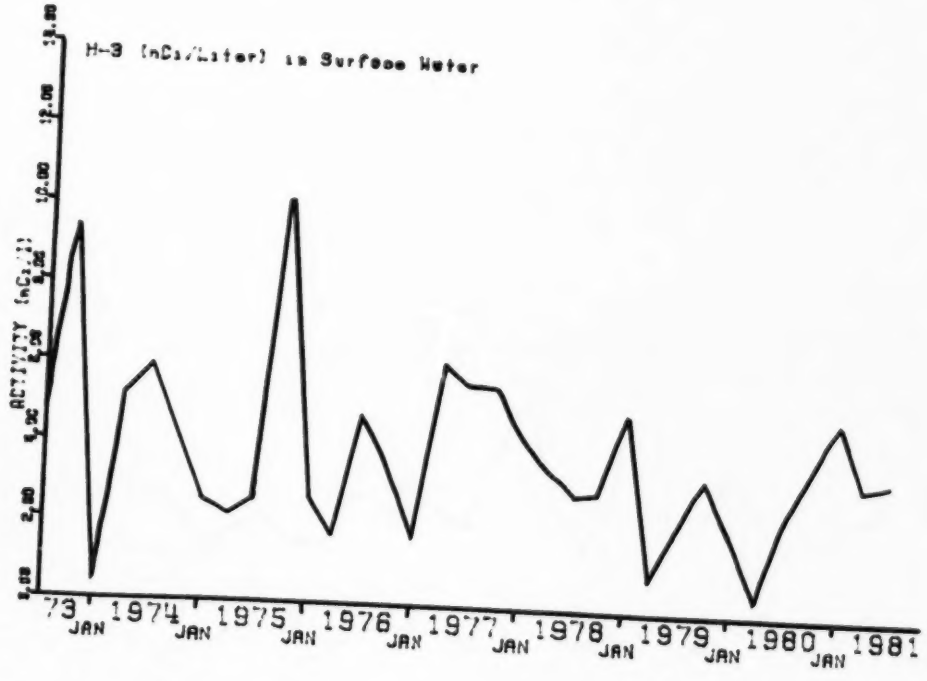


Fig. 4.1-6. Krypton 85 in air samples

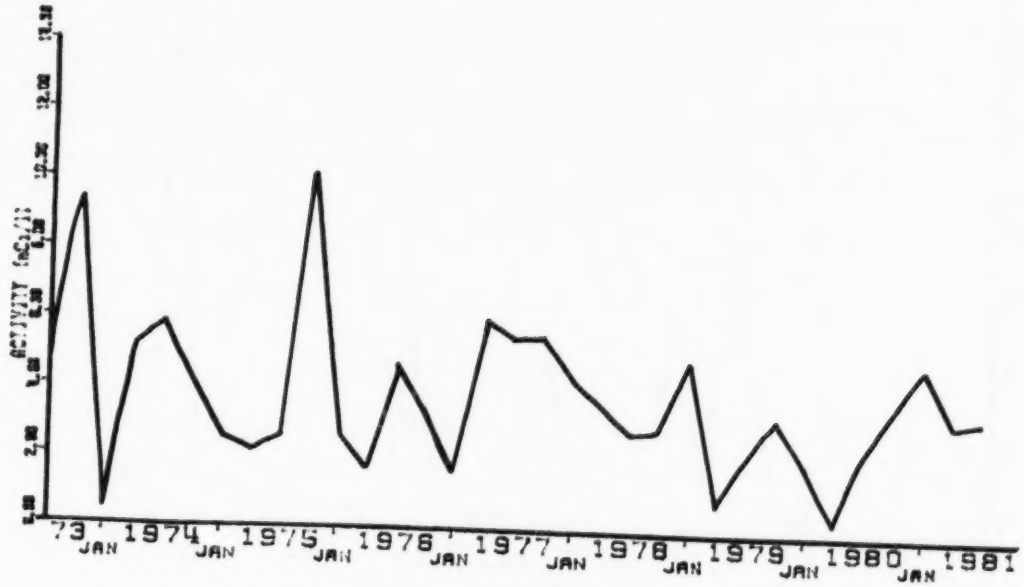


a. Kingston, TN

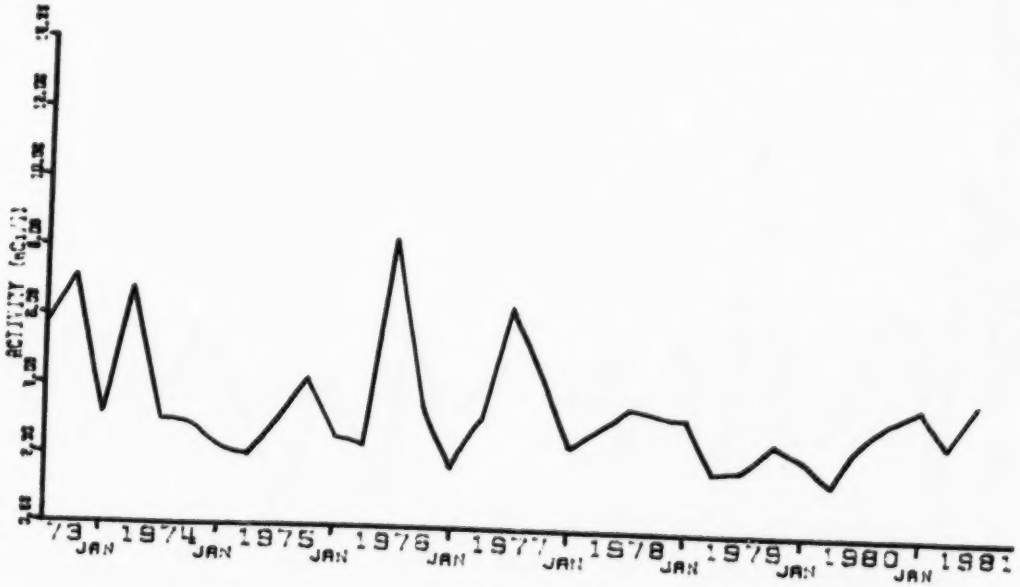


b. Savannah River

Fig. 4.1-7. H-3 in surface water



a. Kingston, TN



b. Savannah River

Fig. 4.1-8 H-3 in drinking water

atmospheric weapon tests in the 1950's and 1960's, the environmental concentration of several important fission products has decreased sharply. One example is a decrease in the concentration of ^{90}Sr in milk as shown in Fig. 4.2-2. Also, concentrations of the prominent fission product, ^{137}Cs, in pasteurized milk have dramatically decreased since the cessation of atmospheric weapons test (see Fig. 4.2-3). Such sharp decreases are quite significant when realizing the corresponding decrease in collective dose to populations.

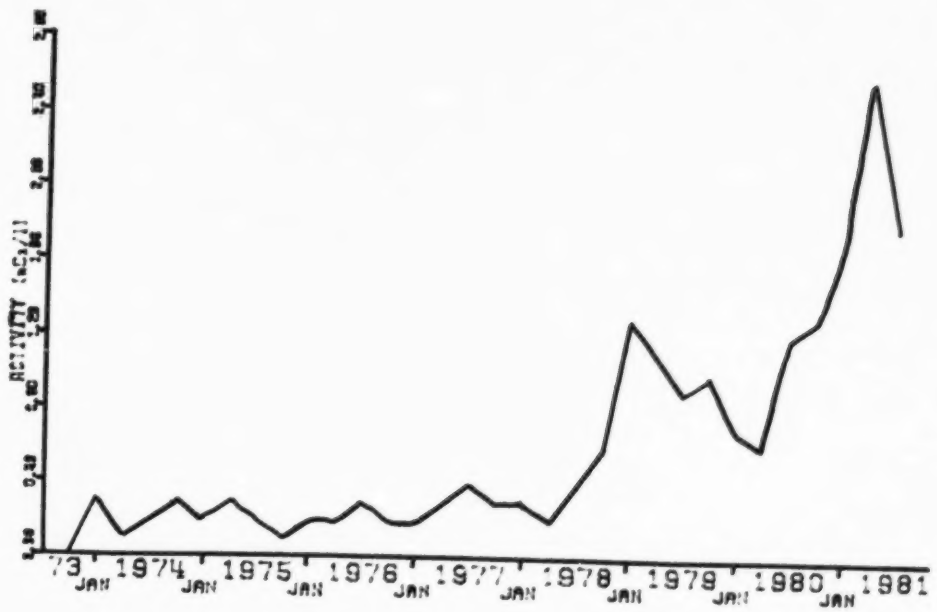


Fig. 4.2-1. H-3 in surface water at Doswell, VA

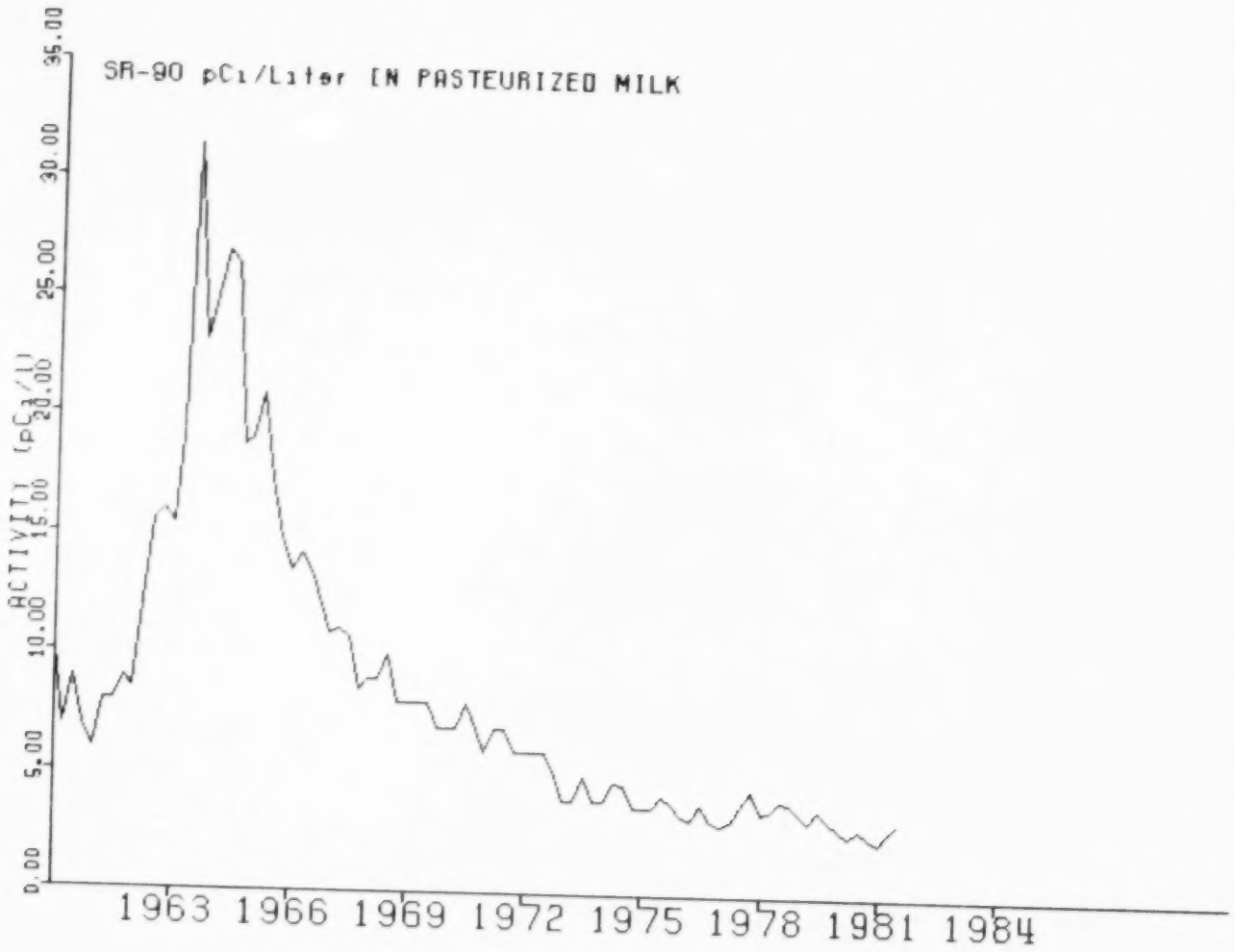


Fig. 4.2-2. Sr-90 in pasteurized milk

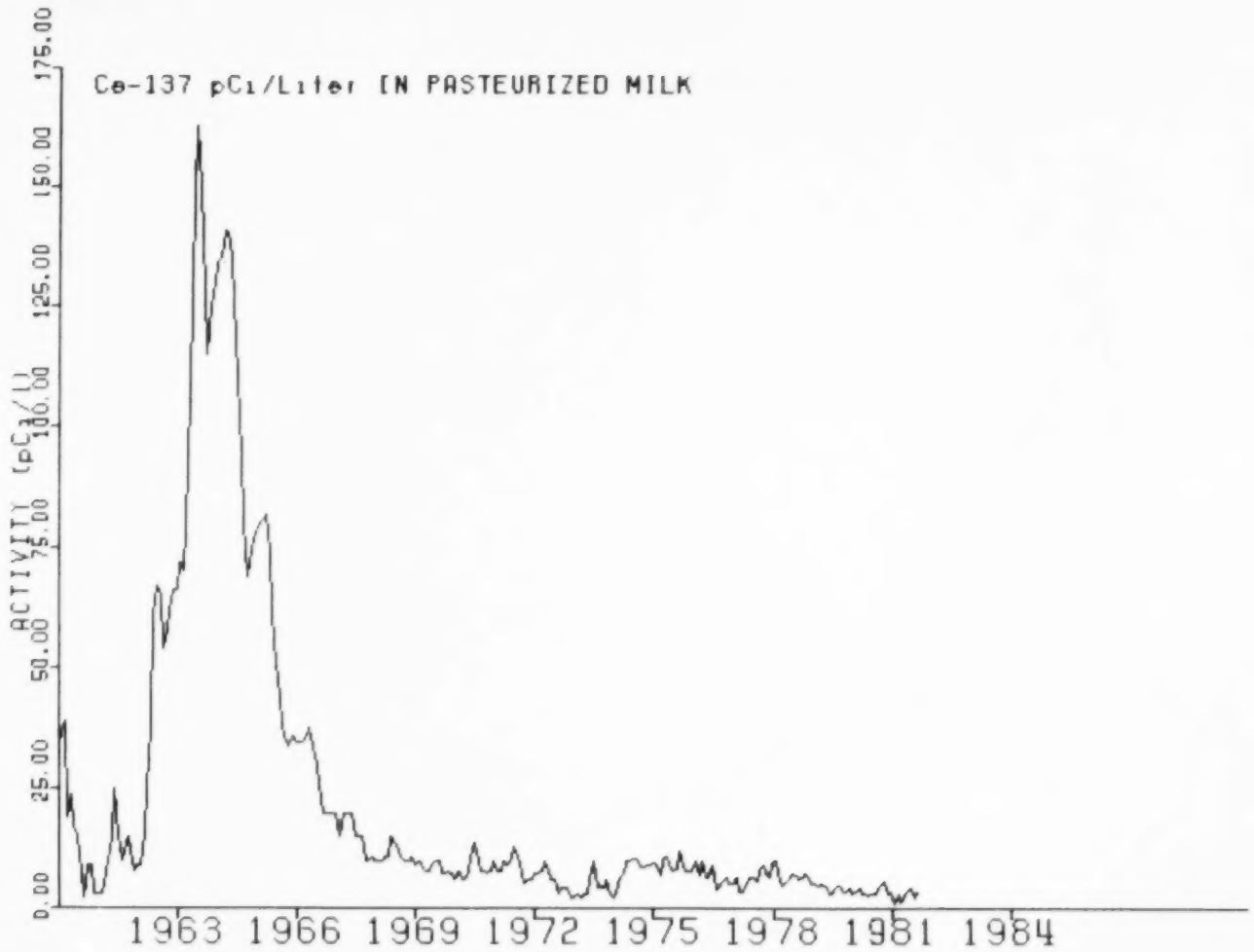


Fig. 4.2-3. Cs-137 in pasteurized milk

5.0 SUMMARY

The ERAMS program is composed of a network of sampling stations throughout the United States plus an associated radioanalytical and assessment support group. These components provide a capability to evaluate environmental consequences from both normal ambient concentrations of radiation and time dependent changes as measured by the samples. The program is structured to measure concentrations of radionuclides in air, milk, surface water, and drinking water and to estimate dose and health impact. Several examples of short-term and long-term assessments of dose and health effect calculations from the ERAMS data base have been presented in this report.

In order to give the reader some perspective for ambient doses received by the U.S. population, Table 6 was prepared to show doses to organs receiving the highest organ doses from milk, inhalation, and external exposure. These displays produced for two-year intervals show slowly decreasing organ doses for the later years. Contributions from ^{40}K are shown to be a signifcant contribution to the total dose received. Based on these assessments, we may state that the U.S. population has not been subjected to significant doses from the radionuclides introduced by mankind into the receptor pathways measured by ERAMS. Furthermore, measurements of a variety of other pathways in previous studies have shown that no pathways of significance were omitted.

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